https://doi.org/10.4082/kjfm.23.0102 • Korean J Fam Med

KJFM

Korean Journal of Family Medicine

eISSN: 2092-6715

■ Original Article

Aquatic versus Land-Based Exercise for Knee Osteoarthritis: A Randomized Controlled Trial

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Background: Whether land- or aquatic-based rehabilitation is more effective in improving knee osteoarthritis (OA) is still unclear. This study assessed the effectiveness of aquatic-based treatments in patients with knee OA.
Methods: The participants were divided into a land-based exercise group (G1, n=30) and a water-based exercise group (G2, n=30). The exercises were performed for 8 weeks. The primary endpoint was a response to physical therapy, defined as a 20% decrease in the summed score for the Western Ontario and McMaster Universities-Osteoarthritis Index (WOMAC) pain subscale from T1 (before the start of the rehabilitation program) to T2 (8 weeks later). The secondary endpoints included the Visual Analog Scale (VAS) for pain, WOMAC functional and stiffness subscales, Lequesne Index, and Medical Outcome Study Short Form (SF-12) for physical and mental health.
Results: A 20% decrease in the summed WOMAC pain subscale score was noted in 33% of patients in G1 (n=10) and 93% in G2 (n=28) (P<0.001). VAS scores at walking decreased by 14% in G1 vs. 37% in G2 (P<0.001), WOMAC stiffness subscale decreased by 18% in G1 vs. 53% in G2 (P<0.001), and the Lequesne index decreased by 10% in G1 vs. 33% in G2 (P<0.001). Quality of life improvement was greater in G2 than in G1; SF-12 (physical) increased by 2.3 in G1 vs. 5.4 in G2 (P=0.023), and SF-12 (mental) increased by 6.3 in G1 vs. 10.9 in G2 (P=0.022).
Conclusion: Both aquatic and land-based exercises improved pain intensity, functional impairment, degree of handicap, and quality of life impairment caused by OA. However, the improvement was more significant in the aquatic-based exercises group.

Keywords: Aquatic Exercises; Osteoarthritis; Knee; Rehabilitation

Received: July 10, 2023, Revised: April 9, 2024, Accepted: May 10, 2024
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INTRODUCTION

Osteoarthritis (OA) is the most common mechanical disorder of the lower limbs. Due to a worldwide increase in the population aged 65 years and over, OA has become a significant public health issue, reducing quality of life and causing functional disabilities. The prevalence of knee OA varies from 7% to 35% and can also affect relatively young participants. Indeed, about half of the 14 million Americans with OA are younger than 65 years.[1)]

The etiopathogenesis of OA is complex and involves genetic and mechanical factors. Several risk factors have been identified, including advanced age, female sex, obesity, osteoporosis, irregular architectural features, and occupation. Therapeutic management of OA requires multidisciplinary approaches to reduce pain, enhance functional impairment, maintain joint range of motion, and improve quality of life.

It has been shown that regular exercise is associated with functional improvement and pain reduction in patients with knee OA.[2,3)] According to the American College of Rheumatology (ACR) guidelines, knee OA rehabilitation programs can combine physiotherapy techniques, muscle strengthening, and proprioceptive work. Rehabilitation programs can be land-based or in an aquatic setting.[4)] Several studies have shown that underwater exercise has beneficial effects on pain relief, muscle building, and joint function.

These effects result from the physical properties of the water. Water buoyancy effects can reduce joint weight bearing, allowing the patient to move effortlessly. Moreover, hydrostatic pressure and constant water temperature help relieve pain, ease soft tissue contracture, reduce knee swelling, and facilitate movement.[5,6)] Muscle strength training can benefit from the resistance caused by water turbulence,[7)] which improves muscle activity and articular range of motion.

However, some studies have not found significant differences between land-based and underwater exercises. Despite the many advantages of aquatic rehabilitation compared to dry land exercise, it is still unclear which is more effective for treating knee OA. This study assessed the effectiveness of aquatic-based treatments in patients with knee OA.

METHODS

1. The Study Design

We conducted a parallel-group randomized controlled trial according to the CONSORT (Consolidated Standards of Reporting Trials) guidelines with blinded assessment over 9 months. The study included 60 patients with knee OA recruited from the outpatient clinic of the Physical and Rehabilitation Medicine Department. These patients were randomized with a block size of two and allocated to either the control group (G1), which received usual care (dry-land classic rehabilitation program), or the intervention group (G2), which received underwater exercise.

2. Inclusion and Exclusion Criteria

Patients were aged ≥40 years and fulfilled the ACR of rheumatology diagnostic criteria for knee OA. All patients were treated with topical non-steroidal anti-inflammatory drugs.

For both groups, exclusion criteria included chronic cardiovascular diseases contraindicating exertion (unbalanced hypertension or angina), neurological disorders (epilepsy), inflammatory rheumatic diseases, severe knee trauma, and crystal-induced arthritis. Patients who had received intra-articular steroid injections or viscosupplementation in the previous year, joint lavage, partial meniscectomy, or had a history of surgery on the lower limbs were also excluded.

In the aquatic rehabilitation group, patients having hydrophobia, bladder dysfunction, or skin lesions (open wounds, infected bed sores, or skin mycosis) were excluded. We also excluded participants with poor adherence to the rehabilitation protocol, defined as those who missed more than 50% of the first six analgesic sessions, more than three sessions of the rehabilitation program, or were unable to exercise for more than 30 minutes during the training program.

3. Physical Therapy Regimens

Physical therapy was performed for 8 weeks, with three sessions per week. Patients in both groups received analgesic techniques during the first six sessions: (1) analgesic and relaxing massage therapy for both knees, including deep transverse massage of painful tendons and relaxation of patellar fins and (2) analgesic physiotherapy, including cryotherapy and electrotherapy (ultrasound, transcutaneous electrical nerve stimulation).

1) Usual care for control group (G1)

The land-based exercise consisted of the following parts: (1) passive, then assisted active mobilization; (2) static strengthening of the quadriceps and hamstrings; (3) stretching exercises for the hamstring muscles; and (4) proprioceptive rehabilitation, in discharge, then in charge, using stable and unstable surfaces. Patients stood on hard, soft supports in bipodal and monopodal stances. Each session lasted 50 minutes.

2) Intervention for G2

The aquatic rehabilitation protocol was supervised by sports educators. The water temperature was 26°C, and patients were immersed to the level of the xiphoid. Each session duration lasted 60 minutes and involved the following parts: (1) warm-up exercises (15 minutes); (2) exercises to gain joint mobility; (3) strengthening and endurance exercises; and (4) proprioceptive training based on positional control of a board held under the foot at various levels of immersion.

4. Data Collection

A single-blinded investigator recorded sociodemographic data and performed clinical examinations to evaluate pain and function. Before the rehabilitation program began, demographic and clinical characteristics were recorded, including age, sex, body mass index (BMI), occupation, physical activity, personal and family medical history, and age at disease onset. The radiographic severity of knee OA was assessed using Kellgren and Lawrence's classification. Patient assessment was performed before the beginning of the rehabilitation program (T1) and 8 weeks later (T2).

The primary outcome measure was the response to physical therapy, defined as a 20% decrease in the summed score for the WOMAC pain subscale (five questions) from T1 to T2.[8] Secondary outcome measures included the evaluation of these parameters:

(1) Pain intensity was evaluated using a Visual Analog Scale (VAS) at rest and during walking.

(2) Stiffness (two questions) and function (17 questions) WOMAC subscales: Each item was rated on a Likert scale (none, 0; minimal, 1; moderate, 2; severe, 3; and extreme, 4). Higher scores indicated a greater functional impact of OA.[9]

(3) The degree of handicap caused by OA was evaluated using the knee-Lequesne index. It comprises 11 questions concerning pain, daily activity, and walking distance.[10] The handicap was classified as absent (score=0), mild (from 1 to 4), moderate (from 5 to 7), severe (from 8 to 10), very severe (from 11 to 13), and extremely severe (score ≥14 means).

(4) Quality of life impairment was evaluated using the Medical Outcome Study Short Form (SF-12).[11] It assesses a patient's perceived health status in the physical and mental domains. Higher scores indicated a better quality of life.

(5) The active range of motion was measured using a universal and reliable goniometer with the patient lying on a bed in the supine position with the knee extended.

(6) Quadricep trophicity was evaluated by measuring the muscle circumference 10 cm above the upper border of the patella. Muscle amyotrophy was defined as a difference between two quadriceps muscles measuring ≥2 cm.

5. Sample Size

The sample size was calculated using data from the study by Silva et al.,[5] we found that a sample size of ≥19 per group would ensure that a two-sided test with α=0.05 has 95% power to detect a significant difference in the primary outcome between G1 and G2.[12]

6. Statistical Analysis

Statistical analysis was performed using the IBM SPSS software ver. 23.0. (IBM Corp., Armonk, NY, USA). Quantitative variables were expressed as mean and standard deviation. Qualitative variables were expressed as numbers and percentages (%). Comparisons of two means on independent series were performed using Student t-test for independent series. Percentages in independent series were compared using Pearson's chi-square test. Fisher's exact test was performed when more than 20% of the cells had expected frequencies of <5. MacNemar's test was used to compare the two percentages in a paired series. Statistical significance was set at P<0.05.

We performed stepwise backward binary logistic regression to alleviate possible confounding effects for the primary outcome and quadriceps trophicity and multiple linear regression for the other secondary endpoints. In this study, we included parameters that were significantly associated (P<0.05) in the univariate analysis and those with a P-value <0.20.

7. Ethical Considerations:

This study was conducted in accordance with the Declaration of Helsinki and approved by the local ethical committee of the Military Hospital of instruction of Tunis. Informed consent was obtained from each patient before randomization. The confidentiality of the data was ensured.

RESULTS

1. Comparison of Patient Characteristics between G1 and G2

All participants demonstrated good adherence. The patient group comprised 14 males and 46 females, resulting in an male/female ratio of 0.3. The mean age was 54.85±9.5 years, and the mean BMI was 30.7 kg/m^2. Only 18% of participants exercised regularly. The patients' characteristics of the two groups are summarized in Table 1.

2. Comparison of Primary and Secondary Outcome Measures before and after Rehabilitation

The primary and secondary outcomes for both groups at baseline and after 8 weeks of rehabilitation are presented in Table 2. After 8 weeks of rehabilitation, land- and aquatic-based exercises improved all assessed parameters except for quadriceps amyotrophy in G2.

Table 1. Demographic, clinical, and radiographic characteristics of the study population

Characteristic	G1 (n=30)	G2 (n=30)	P-value
Age (y)	59.1±10.3	50.6±6.42	<0.001*
Sex			0.015*
Male	3 (21.4)	11 (58.6)	
Female	27 (78.6)	19 (41.3)	
Sex-ratio (male/female)	0.11	0.57	
Body mass index (kg/m^2)	31.6±5.7	28.8±3.8	0.030*
Regular exercise	4 (13.0)	7 (23.0)	0.320
Pain duration (mo)	62.4±53.9	43.7±39.7	0.131
Bilateral knee pain	26 (87.0)	26 (87.0)	1
Kellgren and Lawrence grade			0.332
Grade <3	2 (7.0)	4 (13.0)	
Grade ≥3	28 (93.0)	26 (87.0)	

Values are presented as mean±standard deviation or number (%). Comparisons were made by the Pearson chi-square test for categorical variables, and comparisons were made by Student t-test for continuous variables.
G1, land-based group; G2, aquatic-based group.
*P<0.05 (statistical significance).

https://doi.org/10.4082/kjfm.23.0102

Table 2. Comparison of primary and secondary outcome measures before and after rehabilitation

Variable	G1			G2		
	T1	T2	P-value	T1	T2	P-value
WOMAC pain	14.2±5.1	11.7±4.5	<0.001*	11.3±3.2	5.4±2.4	<0.001*
8WOMAC physical function	45.2±15.7	40.3±14	<0.001*	34±11.2	17.6±8.1	<0.001*
WOMAC stiffness	5.5±2.5	4.5±2.3	<0.001*	4.3±2.6	2±1.5	<0.001*
WOMAC	64.9±22.7	56.5±19.8	<0.001*	49.6±15.8	25.1±11.1	<0.001*
VAS at rest (mm)	2.47±2.3	1.27±1.6	<0.001*	1.8±2.5	0.5±0.9	<0.001*
VAS at walking (mm)	7.7±2	6.6±2.2	<0.001*	7.6±1.8	4.8±1.7	<0.001*
Knee Lequesne index	13.6±4.6	12.2±4.4	<0.001*	10±2.8	6.7±2.1	<0.001*
SF-12 physical	30.6±8.4	32.9±7.3	<0.001*	38.2±7.8	43.6±4.9	<0.001*
SF-12 mental	34.8±10.1	41.1±10.7	<0.001*	35.9±9.6	46.9±9	<0.001*
Range of motion	123.1±13.7	124.4±13	0.016*	133.3±8.8	135.4±7.7	<0.001*
Quadriceps amyotrophy	10 (33.3)	8 (26.7)	<0.001*	9 (30.0)	4 (13.3)	0.074

Values are presented as mean±standard deviation or number (%) unless otherwise stated. Comparisons were made by the Pearson chi-square test for categorical variables, and comparisons were made by Student t-test for continuous variables.
G 1, land-based exercise group; G2, aquatic-based exercise group; T1, at baseline; T2, at 8 weeks; WOMAC, Western Ontario and McMaster Universities-Osteoarthritis Index; VAS, Visual Analog Scale; SF-12, Medical Outcome Study Short Form.
*P<0.05 (statistical significance).

Table 3. Comparison between the difference of primary and secondary outcome measures before and after rehabilitation between the two groups (G1 and G2)

Variable	G1			G2			P-value
	T1	T2	Δ	T1	T2	Δ	
WOMAC pain	14.2±5.1	11.7±4.5	-2.53±1.9	11.3±3.2	5.4±2.4	-5.8±3.1	<0.001*
20% decrease in the WOMAC pain	-	-	10 (33.3)	-	-	28 (93.3)	<0.001*
WOMAC physical function	45.2±15.7	40.3±14.0	-4.9±3.9	34±11.2	17.6±8.1	-16.4±9.4	<0.001*
WOMAC stiffness	5.5±2.5	4.5±2.3	-1±1.1	4.3±2.6	2.0±1.5	-2.3±1.9	0.003*
WOMAC	64.9±22.7	56.5±19.8	-8.5±6.3	49.6±15.8	25.1±11.1	-24.5±13.4	<0.001*
VAS at rest (mm)	2.47±2.3	1.27±1.6	-1.2±1.6	1.8±2.5	0.5±0.9	-1.3±2.1	0.781
VAS at walking (mm)	7.7±2.0	6.6±2.2	-1.1±1.3	7.6±1.8	4.8±1.7	-2.8±1.7	<0.001*
Knee Lequesne index	13.6±4.6	12.2±4.4	-1.4±1.1	10.0±2.8	6.7±2.1	-3.3±2.1	<0.001*
SF-12 physical (mm)	30.6±8.4	32.9±7.3	2.3±3.6	38.2±7.8	43.6±4.9	5.4±6.2	0.023*
SF-12 mental (mm)	34.8±10.1	41.1±10.7	6.3±7.3	35.9±9.6	46.9±9.0	10.9±7.9	0.026*
Range of motion	123.1±13.7	124.4±13.0	1.3±2.4	133.3±8.8	135.4±7.7	2.1±3.1	0.282
Quadriceps amyotrophy	10 (33.3)	8 (26.7)	2 (6.6)	9 (30.0)	4 (13.3)	5 (16.7)	0.094

Values are presented as mean±standard deviation or number (%) unless otherwise stated. Comparisons were made by the Mac Nemar test for categorical variables, and comparisons were made by Student t-test for continuous variables.
G 1, land-based exercise group; G2, aquatic-based exercise group; T1, at baseline; T2, at 8 weeks; Δ, difference between T1 and T2; WOMAC, Western Ontario and McMaster Universities-Osteoarthritis Index; VAS, Visual Analog Scale; SF-12, Medical Outcome Study Short Form.
*P<0.05 (statistical significance).

3. Comparison between the Difference of Primary and Secondary Outcome Measures before and after Rehabilitation between G1 and G2

As depicted in Table 3, aquatic-based exercise was more effective than land-based exercise for pain intensity (WOMAC pain subscale and VAS during walking), functional impairment (WOMAC function subscale), degree of handicap caused by OA (Lequesne score index), and quality of life impairment (SF-12).

The WOMAC pain subscale decreased by 5.8±3.1 (50%) in G2 and 2.53±1.9 (17%) in G1 (P<0.001). A 20% decrease in the summed score for the WOMAC pain subscale was noted in 33% of the patients in G1 (n=10) and 93% in G2 (n=28) (P<0.001). At T2, WOMAC stiffness decreased by 2.3±1.9 in G2 (53%) versus 1±1.1 in G1 (18%) (P=0.003), and WOMAC function decreased by 16.4±9.4 in G2 (48%) versus 4.9±3.9 in G1 (11%) (P<0.001). Additionally, the Lequesne Index has decreased by 3.3±2.1 (33%) in G2 versus 1.4±1.1 (10%) in G1 (P<0.001).

The SF-12 physical index increased by 2.3 in the land-based exercise group versus 5.4 points on average in the aquatic rehabilitation group (P=0.02). Similarly, the SF-12 mental index increased by 6.3 in G1 versus 10.9 in G2 (P=0.02). Nevertheless, no differences were observed between these two types of exercises regarding their effect on pain intensity at rest, range of motion of the knee, and quadriceps trophicity.

4. Adjustment for Confounders (Multivariate Analysis)

We conducted multiple logistic regression for the main endpoint and multiple linear regression for the secondary endpoints using uneven variables, including age, sex, and BMI, as covariates. Multivariate analysis revealed that, compared to land-based exercise, water-based intervention significantly improved WOMAC pain, function, and stiffness subscales, VAS pain scores, and SF-12 quality of life score after adjusting for age, sex, and BMI (Tables 4, 5).

DISCUSSION

In this study, we assessed the effectiveness of aquatic- and land-based rehabilitation in patients with knee OA.

Our findings showed that both water- and land-based exercises improved VAS pain on effort, WOMAC scores, Lequesne Index, and SF-12 physical and mental quality of life scores in patients with knee OA. However, the improvement in the aquatic rehabilitation group was greater in terms of pain and functional impairment, which are major sources of disability in patients with OA. Therapeutic management of knee OA remains challenging, aiming to control pain, enhance joint mobility, and improve performance capacity.[4,13]

According to the latest recommendations from the Osteoarthritis Research Society International recommendations, management should be personalized based on the patient's general risk factors, pain intensity, degree of functional limitation, and joint structural damage.[14] In addition to pharmacological treatments, rehabilitation exercises are fundamental in knee OA management. Chronic pain and long-term inactivity lead to articular stiffness and worsened muscle function, highlighting the importance of exercise programs in knee OA management. While rehabilitation programs offer similar benefits to pharmacological treatments, they have a lower evidence level due to the complexity of interventions and methodology used (such as lack of long-term studies and difficulty in double-blinding).

Both land-based and aquatic exercises are viable options. The effectiveness of land-based exercises in reducing pain and improving function has been reported in several studies showing the enhancement of muscle strength, flexibility, proprioception, and endurance. These therapeutic exercises provide short-term benefits that can be maintained for 6 months.[15-18]

Several studies have reported the benefits of aquatic exercise in patients with musculoskeletal disorders. They demonstrated that this therapeutic option was safe and effective in relieving pain and improving quality of life.[19,20]

These results are consistent with those of previous studies. Rewald et al.[21] demonstrated improvements in self-reported knee pain, physical functioning, and quality of life after 12 weeks of an aquatic cycling training program in patients with mild to moderate knee OA. Similarly, Bartels et al.[22] showed a moderately beneficial effect of aquatic therapy on pain and quality of life in patients with knee and hip OA.

We also compared the effectiveness of aquatic- and land-based rehabilitation methods. A 20% decrease in the summed score for the WOMAC pain subscale was noted in 33% of the patients in G1 versus 92% in G2 (P<0.001). Moreover, aquatic-based exercise was more effective than land-based exercise in reducing pain intensity (VAS) during walking, functional impairment (WOMAC score), degree of handicap caused by OA (Lequesne score index), and quality-of-life impair-

Table 4. Binary logistic regression for primary endpoint and quadriceps trophicity

Variable	Adjusted OR (95% CI)	P-value
20% decrease in WOMAC pain		
Water-based exercise	0.013 (0.002–0.098)	<0.001*
Age	1.093 (1.006–1.188)	0.036*
Quadriceps trophicity		
Water-based exercise	2.355 (0.341–16.24)	0.385
Sex	4.539 (0.394–5.221)	0.225
Body mass index	0.789 (0.659–0.946)	0.010*
Age	0.915 (0.834–1.004)	0.061

OR, odds ratio; CI, confidence interval; WOMAC, Western Ontario and McMaster Universities-Osteoarthritis Index.
*P<0.05 (statistical significance).

Table 5. Multiple linear regression analysis for secondary endpoints

Variable	Category	B	SE	β	95% CI	P-value
VAS pain at rest	Water-based exercise	-0.800	0.348	-0.289	-1.49 to -0.10	0.025*
VAS pain at walking	Water-based exercise	-1.493	0.508	-0.352	-2.51 to -0.47	0.005*
	BMI	0.110	0.050	0.262	0.09 to 0.21	0.033*
Knee Lequesne index	Water-based exercise	-3.568	0.829	-0.408	-5.22 to -1.90	<0.001*
	BMI	0.350	0.076	0.404	0.19 to 0.50	<0.001*
	Age	0.110	0.044	0.236	0.02 to 0.19	0.015*
SF-12 (physical)	Water-based exercise	9.466	1.602	0.582	6.25 to 12.67	<0.001*
	BMI	-0.418	0.159	-0.260	-0.73 to -0.10	0.011*
SF-12 (mental)	Water-based exercise	8.387	2.789	0.412	2.80 to 13.97	0.004*
	Age	0.307	0.148	0.284	0.01 to 0.60	0.042*
Womac physical function	Water-based exercise	-16.336	2.741	-0.510	-21.82 to -10.84	<0.001*
	BMI	1.155	0.251	0.364	0.65 to 1.65	<0.001*
	Age	0.370	0.145	0.218	0.08 to 0.65	0.013*
Womac stiffness	Water-based exercise	-1.987	0.483	-0.438	-2.95 to -1.02	<0.001*
	BMI	0.160	0.048	0.356	0.06 to 0.25	0.001*

SE, standard error; CI, confidence interval; VAS, Visual Analog Scale; BMI, body mass index; SF-12, Medical Outcome Study Short Form; WOMAC, Western Ontario and McMaster Universities-Osteoarthritis Index.
*P<0.05 (statistical significance).

https://doi.org/10.4082/kjfm.23.0102

ment (SF-12). However, no differences were observed between these two types of exercises regarding their effect on the range of motion of the knee and quadriceps trophicity.

Other studies have reported similar effects of aquatic and land-based rehabilitation.[23-25] However, Song and Oh[26] concluded that aquatic exercise was more effective in reducing pain in patients. It has been suggested that water characteristics, especially temperature and pressure, could help alleviate joint symptoms by relaxing muscles and soothing nerve endings.[27]

In addition to physical disability, mental health appears to be highly influenced by knee OA.[28] Comparisons of 36-Item Short Form Health Survey scores for various chronic diseases showed that osteoarticular factors have a significant impact on quality of life.[29]

In our study, an improvement in the SF-12 scores was reported in both groups at the end of the follow-up period. This improvement was more significant in the hydrotherapy group, supporting the psychological impact of water.[30]

Hydrotherapy has been practiced for centuries and is based on the physical and chemical properties of water. The aquatic environment also seems to positively influence pain perception and increase well-being. These effects last for several months and may even enable patients to reduce their use of analgesics.[31] Given the positive effects of aquatic exercise, especially on pain relief, this therapeutic intervention is recommended by experts in knee OA management.[14]

However, these recommendations are conditional on accessibility and economic considerations. Moreover, relevant guidelines for determining optimal water conditions and exercise modalities remain unclear. Thus, it is necessary to specify water characteristics, such as temperature, depth, and composition, in each rehabilitation program. Differences in temperature and depth offer varying exercise conditions and may impact study outcomes. In this study, we used tap water and considered only its physical properties. The water temperature was 26°C, and the patients were immersed to the xiphoid level.

Our study had some limitations, including the relatively short follow-up duration. Moreover, despite employing a block randomization procedure to achieve balance in basic characteristics and increase comparability between the groups, we observed significant differences in age, BMI, and sex ratio between G1 and G2. To mitigate potential confounding effects, we performed a multivariate analysis, which confirmed the superiority of aquatic rehabilitation over land-based exercise in our population.

Further studies with detailed exercise descriptions are warranted to determine the optimal conditions for sustaining the therapeutic effects of aquatic rehabilitation and establish precise guidelines.

In conclusion, our study demonstrated that both aquatic and land-based exercises effectively improved pain intensity, functional impairment, degree of handicap, and quality of life impairment associated with knee OA. Importantly, the improvement observed was significantly greater in the aquatic-based exercise group compared to the control group. These findings underscore the efficiency of both techniques in rehabilitating patients with knee OA.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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