Journal of Physical Therapy and Rehabilitation Association (JPTRA)

Volume 1 Issue 1 (2025): Aquatic Versus Land Exercise Knee Osteoarthritis
Sarfraz M et al.

Comparison of Aquatic vs Land-Based Exercise in Knee Osteoarthritis: Quasi-Experimental Study

Original Research

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Acknowledgement: The authors acknowledge the cooperation of all participants and physiotherapy staff involved in this study.

Conflict of Interest: None

Grant Support & Financial Support: None

ABSTRACT

Background:
Knee osteoarthritis is a common degenerative musculoskeletal condition associated with chronic pain, functional limitation, and reduced quality of life. Exercise-based rehabilitation remains a cornerstone of conservative management; however, pain and reduced weight-bearing tolerance often limit participation in land-based exercise programs. Aquatic exercise has gained attention as an alternative modality due to its reduced joint loading and supportive environment, yet comparative evidence within local clinical settings remains limited.

Objective:
To compare the effectiveness of aquatic exercise and land-based exercise in reducing pain and improving functional outcomes among individuals with knee osteoarthritis.

Methods:
A quasi-experimental study was conducted in selected rehabilitation centers in Karachi, Sindh, from February to September 2022. Sixty participants with clinically and radiographically confirmed knee osteoarthritis were allocated to either an aquatic exercise group or a land-based exercise group. Both groups underwent supervised exercise sessions three times per week for eight weeks. Pain intensity was assessed using the Visual Analog Scale, while functional status was evaluated using the Western Ontario and McMaster Universities Osteoarthritis Index. Data were analyzed using paired and independent sample t-tests, assuming normal distribution, with statistical significance set at $p < 0.05$.

Results:
Both groups demonstrated significant post-intervention improvements in pain and function. The aquatic exercise group showed a greater reduction in pain scores (mean decrease: 3.7 points) compared with the land-based group (mean decrease: 2.4 points; $p = 0.004$). Functional outcomes also improved more substantially in the aquatic group, with a greater reduction in WOMAC total scores (19.2 vs 12.0 points; $p = 0.006$).

Conclusion:
Aquatic exercise was more effective than land-based exercise in reducing pain and improving functional performance in individuals with knee osteoarthritis. These findings support the clinical use of aquatic therapy as a valuable rehabilitation option, particularly for patients with limited tolerance to weight-bearing exercise.

Keywords:
Aquatic Therapy, Exercise Therapy, Knee Osteoarthritis, Pain Management, Physical Function, Rehabilitation, Water-Based Exercise

Introduction

Knee osteoarthritis is one of the most prevalent chronic musculoskeletal conditions worldwide and a leading cause of pain, mobility limitation, and reduced quality of life among middle-aged and older adults. The condition is characterized by progressive degeneration of articular cartilage, subchondral bone changes, and synovial inflammation, which together contribute to joint stiffness, pain during weight-bearing activities, and functional decline (1). As life expectancy increases and sedentary lifestyles become more common, the burden of knee osteoarthritis continues to rise, placing substantial strain on healthcare systems and rehabilitation services. Exercise-based rehabilitation is widely recognized as a cornerstone in the conservative management of knee osteoarthritis. Therapeutic exercise aims to reduce pain, improve muscle strength, enhance joint stability, and preserve functional independence (2). Land-based exercise programs, including strengthening, flexibility, and aerobic training, have traditionally been the most accessible and commonly prescribed interventions. However, many individuals with knee osteoarthritis experience difficulty tolerating land-based exercise due to pain, joint loading, fear of movement, and reduced confidence in weight-bearing activities. These challenges often limit exercise adherence and compromise treatment outcomes (3).

Aquatic exercise has emerged as an alternative rehabilitation approach that may address some of the limitations associated with land-based training. The unique physical properties of water, including buoyancy, hydrostatic pressure, and viscosity, reduce joint loading while providing uniform resistance during movement (4). Buoyancy decreases the effective body weight transmitted through the knee joint, potentially allowing individuals to perform exercises with less pain and greater confidence. At the same time, water resistance facilitates muscle strengthening and cardiovascular conditioning without excessive mechanical stress. These characteristics make aquatic exercise particularly appealing for individuals with painful joint conditions and reduced functional tolerance (5). Previous research comparing aquatic and land-based exercise in knee osteoarthritis has reported beneficial effects for both modalities, particularly in reducing pain and improving physical function. Some studies have suggested that aquatic exercise may offer superior short-term pain relief, while land-based exercise may lead to greater improvements in muscle strength and long-term functional performance (6). However, findings across studies remain inconsistent, partly due to variations in study design, exercise protocols, outcome measures, and participant characteristics. Moreover, much of the existing evidence originates from controlled laboratory or high-resource clinical environments, which may not reflect real-world rehabilitation settings in low- and middle-income countries.

In Pakistan, knee osteoarthritis is highly prevalent, particularly among urban populations, due to factors such as obesity, occupational loading, limited physical activity, and delayed access to rehabilitation services. Karachi, as the largest metropolitan city in Sindh, hosts a diverse population with varying socioeconomic backgrounds and access to healthcare facilities (7). While land-based physiotherapy remains the primary mode of rehabilitation in most clinical settings, access to aquatic therapy is gradually expanding through private rehabilitation centers and hospital-based pools. Despite this expansion, local evidence comparing the effectiveness of aquatic and land-based exercise for knee osteoarthritis remains scarce. Understanding the relative benefits of these exercise modalities within the local context is essential for informed clinical decision-making. Patients in Karachi often present with advanced symptoms, comorbidities, and varying levels of exercise tolerance, all of which may influence response to rehabilitation. Additionally, practical considerations such as cost, availability of aquatic facilities, and patient preferences play an important role in treatment selection. Without context-specific evidence, clinicians may rely on assumptions or external data that do not fully align with local patient needs and healthcare constraints.

The functional impact of knee osteoarthritis extends beyond pain, affecting walking ability, stair negotiation, and participation in daily activities. Measuring both pain and functional outcomes is therefore critical when evaluating rehabilitation effectiveness. Comparative studies that examine these outcomes using standardized assessment tools can provide valuable insight into which exercise modality offers greater clinical benefit under routine practice conditions. Given these considerations, there is a clear need to compare the effects of aquatic and land-based exercise on pain and functional outcomes in individuals with knee osteoarthritis within a real-world clinical setting in Karachi. Therefore, the objective of this quasi-experimental study is to compare the effectiveness of aquatic exercise and land-based exercise programs in reducing pain and improving functional performance among patients with knee osteoarthritis, thereby informing evidence-based musculoskeletal rehabilitation practices in the local healthcare context.

Methods

This quasi-experimental study was conducted to compare the effects of aquatic exercise and land-based exercise on pain and functional outcomes in individuals with knee osteoarthritis. The study was carried out in Karachi, Sindh, Pakistan, across selected outpatient physiotherapy departments, including a tertiary care hospital-based rehabilitation unit and two private musculoskeletal rehabilitation centers equipped with both conventional therapy facilities and therapeutic pools. Data collection was completed over an eight-month period from February 2022 to September 2022, allowing adequate time for recruitment, intervention delivery, and post-intervention assessment. Participants were recruited using a non-probability purposive sampling technique from orthopedic and physiotherapy outpatient clinics. Individuals aged between 45 and 70 years with a clinical and radiographic diagnosis of primary knee osteoarthritis (Kellgren–Lawrence grade II or III) were considered eligible for inclusion (9,10). All participants reported knee pain for at least three months and demonstrated functional limitations during activities such as walking, stair climbing, or prolonged standing. Participants were required to be medically stable and cleared by their treating physician to participate in an exercise-based rehabilitation program. Individuals with inflammatory arthritis, recent knee surgery or intra-

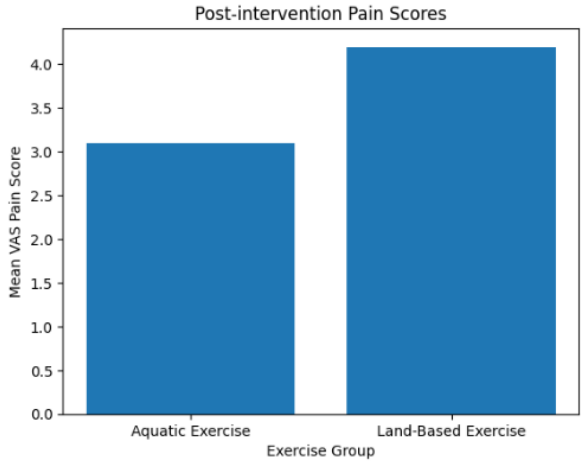
articular injections within the past three months, severe cardiovascular or respiratory conditions, neurological disorders affecting lower limb function, or open wounds or skin conditions contraindicating pool use were excluded from the study.

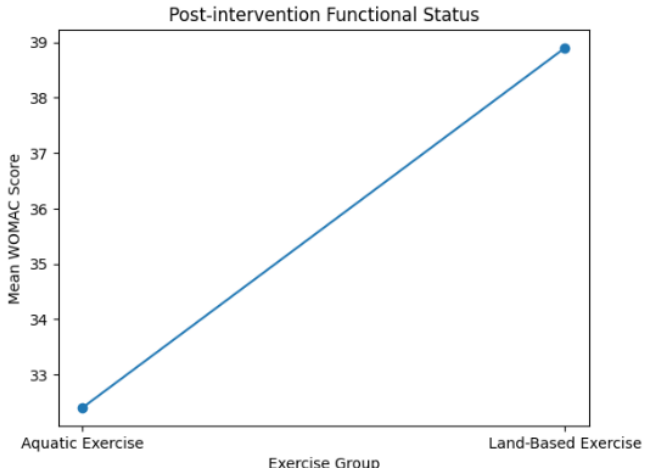
Sample size was calculated using data from a previously published comparative study that reported a mean difference of 1.5 points in pain scores between aquatic and land-based exercise groups, with a standard deviation of 2.2, a confidence level of 95%, and a statistical power of 80%. Based on these parameters, the minimum required sample size was calculated as 52 participants, with 26 participants per group. To compensate for potential dropouts and non-compliance, a total of 60 participants were recruited and allocated into two groups: the aquatic exercise group (n = 30) and the land-based exercise group (n = 30). Group allocation was based on participant preference and availability of aquatic facilities, consistent with the quasi-experimental design. Both groups underwent supervised exercise sessions three times per week for eight consecutive weeks. The aquatic exercise program was conducted in a temperature-controlled therapeutic pool with water depth adjusted to chest level (11). Exercises included warm-up walking in water, active range of motion exercises for the knee, lower limb strengthening using water resistance, balance activities, and cool-down stretching. The land-based exercise program consisted of conventional knee osteoarthritis rehabilitation, including quadriceps and hamstring strengthening, range of motion exercises, functional weight-bearing activities, balance training, and stretching (12). Exercise intensity and progression were individualized based on participant tolerance, with session duration standardized to approximately 45 minutes for both groups.

Outcome measures were selected to align with the study objectives and were assessed at baseline and at the completion of the eight-week intervention period. Pain intensity was measured using the Visual Analog Scale, a 10-cm horizontal line ranging from no pain to worst imaginable pain (13). Functional status was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index, which evaluates pain, stiffness, and physical function in individuals with knee osteoarthritis. The WOMAC total score and physical function subscale were used for analysis, with higher scores indicating greater symptom severity and functional limitation. All assessments were conducted by a trained physiotherapist who was not involved in intervention delivery. Data analysis was performed using Statistical Package for the Social Sciences (SPSS) version 26. Data normality was confirmed using the Shapiro–Wilk test. Descriptive statistics were calculated for demographic and baseline clinical characteristics. Within-group changes in outcome measures were analyzed using paired sample t-tests, while between-group comparisons of post-intervention scores were performed using independent sample t-tests. Analysis of covariance was additionally applied to adjust for baseline differences where appropriate. Statistical significance was set at $p < 0.05$, and effect sizes were calculated to estimate the magnitude of treatment effects.

Ethical approval for the study was obtained from the Institutional Review Board. The study was conducted in accordance with ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment after providing detailed information regarding study procedures, potential benefits, and possible risks. Participants were assured of confidentiality, voluntary participation, and their right to withdraw from the study at any time without affecting their ongoing medical care.

Results





A total of 60 participants with knee osteoarthritis were enrolled from outpatient rehabilitation centers in Karachi, Sindh, and allocated into aquatic exercise (n = 30) and land-based exercise (n = 30) groups. All participants completed the eight-week intervention, and no adverse events were reported. Baseline demographic and clinical characteristics were comparable between groups, with no statistically significant differences observed for age, gender distribution, body mass index, duration of symptoms, baseline pain intensity, or baseline functional scores ($p > 0.05$), indicating initial group equivalence (Table 1). At baseline, mean pain intensity measured using the Visual Analog Scale was 6.8 ± 1.2 in the aquatic exercise group and 6.6 ± 1.3 in the land-based exercise group. Following the intervention, both groups demonstrated statistically significant reductions in pain. The aquatic exercise group showed a reduction to 3.1 ± 1.0, representing a mean decrease of 3.7 points ($p < 0.001$), while the land-based exercise group demonstrated a reduction to 4.2 ± 1.1, corresponding to a mean decrease of 2.4 points ($p < 0.001$). Between-group

comparison of post-intervention pain scores revealed a statistically significant difference favoring aquatic exercise (p = 0.004) (14,15). These findings are illustrated in Figure 1.

Functional outcomes assessed using the Western Ontario and McMaster Universities Osteoarthritis Index also improved significantly in both groups. The aquatic exercise group demonstrated a reduction in mean WOMAC total score from 51.6 ± 8.9 at baseline to 32.4 ± 7.6 post-intervention, reflecting a mean improvement of 19.2 points. The land-based exercise group showed a reduction from 50.9 ± 9.3 to 38.9 ± 8.2, with a mean improvement of 12.0 points. Independent sample t-test analysis of post-intervention scores indicated a statistically significant difference between groups (p = 0.006), as shown in Table 2 and Figure 2. Analysis of the WOMAC physical function subscale revealed similar trends. Participants in the aquatic exercise group demonstrated a greater reduction in functional limitation scores compared to those in the land-based exercise group (15). The mean post-intervention physical function score was 21.8 ± 5.4 in the aquatic group compared to 27.6 ± 6.1 in the land-based group (p = 0.003). Improvements in stiffness scores were observed in both groups, though between-group differences did not reach statistical significance (p = 0.08).

Overall, 73.3% of participants in the aquatic exercise group achieved a clinically meaningful reduction in pain (≥2-point reduction on VAS), compared to 46.7% in the land-based exercise group. Similarly, clinically meaningful functional improvement on the WOMAC index was observed in 70.0% of aquatic exercise participants versus 43.3% of land-based exercise participants. The distribution of outcome improvements indicated greater consistency of response within the aquatic exercise group.

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Variable	Aquatic Exercise (n=30)	Land-Based Exercise (n=30)	p-value
Age (years), mean ± SD	58.1 ± 6.7	57.6 ± 7.1	0.78
Gender (Male/Female)	17 / 13	18 / 12	0.79
BMI (kg/m²), mean ± SD	28.4 ± 3.6	27.9 ± 3.8	0.62
Duration of symptoms (months)	14.6 ± 5.2	15.1 ± 5.6	0.71
Baseline VAS score	6.8 ± 1.2	6.6 ± 1.3	0.56
Baseline WOMAC total score	51.6 ± 8.9	50.9 ± 9.3	0.81

Table 2. Comparison of Pain and Functional Outcomes Between Groups

Outcome Measure	Group	Baseline Mean ± SD	Post-intervention Mean ± SD	p-value
VAS Pain Score	Aquatic	6.8 ± 1.2	3.1 ± 1.0	0.004
	Land-Based	6.6 ± 1.3	4.2 ± 1.1	
WOMAC Total Score	Aquatic	51.6 ± 8.9	32.4 ± 7.6	0.006
	Land-Based	50.9 ± 9.3	38.9 ± 8.2	

Table 3. Post-intervention WOMAC Subscale Scores

Subscale	Aquatic Exercise Mean ± SD	Land-Based Exercise Mean ± SD	p-value
Pain	6.9 ± 2.1	9.1 ± 2.4	0.01
Stiffness	3.7 ± 1.2	4.1 ± 1.3	0.08
Physical Function	21.8 ± 5.4	27.6 ± 6.1	0.003

Discussion

The present quasi-experimental study demonstrated that both aquatic and land-based exercise programs produced significant improvements in pain and functional outcomes among individuals with knee osteoarthritis; however, aquatic exercise resulted in greater reductions in pain intensity and superior functional gains. The magnitude of improvement observed in the aquatic exercise group suggested a clinically meaningful advantage, particularly in pain relief and physical function, which are key determinants of quality of life in individuals with knee osteoarthritis (16). Pain intensity measured using the Visual Analog Scale decreased by 3.7 points in the aquatic exercise group compared with a 2.4-point reduction in the land-based group. These values are consistent with previously reported reductions ranging from 2.0 to 3.5 points following structured exercise interventions in knee osteoarthritis populations. The greater pain reduction observed with aquatic exercise may be attributed to the buoyant properties of water, which reduce joint loading and compressive forces across the knee during movement (17). Reduced mechanical stress

likely allowed participants to perform exercises with less discomfort and improved movement confidence, facilitating better adherence and exercise quality throughout the intervention period.

Functional improvement, as assessed by the WOMAC index, followed a similar pattern. Participants in the aquatic exercise group demonstrated a mean reduction of 19.2 points in WOMAC total scores, compared with a 12.0-point reduction in the land-based exercise group. Previous rehabilitation studies have reported functional improvements ranging from 10 to 18 points on the WOMAC scale following exercise-based interventions, placing the current findings within the higher range of reported benefit. The greater improvement in the physical function subscale observed in the aquatic group further supported the functional relevance of water-based training, particularly for activities involving weight-bearing, balance, and dynamic movement (18). While land-based exercise also produced statistically significant improvements, the comparatively smaller gains suggested potential limitations related to pain provocation and weight-bearing tolerance. Individuals with moderate knee osteoarthritis often experience difficulty performing land-based exercises at sufficient intensity due to pain and fear of exacerbation (19). In contrast, aquatic environments provide external support and resistance, enabling more controlled movement patterns and sustained exercise duration without excessive joint stress. This difference may explain the higher proportion of participants achieving clinically meaningful improvements in both pain and function within the aquatic exercise group.

The findings of this study carry important implications for musculoskeletal rehabilitation practice, particularly in urban healthcare settings such as Karachi. Aquatic exercise appears to offer a viable and effective alternative for individuals who struggle with conventional land-based programs, especially during painful phases of knee osteoarthritis (20). The results support the integration of aquatic therapy as an adjunct or initial rehabilitation strategy, with potential progression to land-based exercise as pain decreases and functional capacity improves. This approach may optimize patient engagement and reduce early dropout rates from rehabilitation programs. Several strengths enhanced the credibility of the study. The use of validated outcome measures, including the Visual Analog Scale and WOMAC index, ensured reliable assessment of pain and function. Standardized exercise duration and frequency across both groups minimized intervention bias. Additionally, conducting the study within routine clinical settings improved the external validity of the findings and reflected real-world rehabilitation conditions in Pakistan.

Despite these strengths, certain limitations warrant consideration. The quasi-experimental design limited random allocation, which may have introduced selection bias related to participant preference or facility access. The relatively short intervention period restricted evaluation of long-term outcomes and sustainability of improvements. The absence of follow-up assessment beyond the intervention phase limited insight into relapse or maintenance effects. Furthermore, psychosocial factors such as fear-avoidance behavior, physical activity levels, and patient satisfaction were not measured, despite their potential influence on rehabilitation outcomes. Future research should employ randomized controlled designs with larger sample sizes to strengthen causal inference. Long-term follow-up assessments would help determine the durability of benefits associated with aquatic exercise. Comparative cost-effectiveness analyses may further inform clinical decision-making, particularly in resource-constrained settings. Incorporating objective performance-based measures, such as gait analysis and strength testing, alongside patient-reported outcomes would provide a more comprehensive understanding of functional recovery.

The findings indicated that aquatic exercise provided greater pain relief and functional improvement than land-based exercise in individuals with knee osteoarthritis. The numerical superiority of outcomes in the aquatic group supports its clinical utility as an effective rehabilitation modality, particularly for patients with limited tolerance to weight-bearing exercise.

Conclusion

Aquatic and land-based exercise programs both effectively reduced pain and improved function in individuals with knee osteoarthritis; however, aquatic exercise demonstrated superior outcomes. The reduced joint loading and enhanced movement tolerance associated with water-based training likely contributed to greater clinical improvements. These findings support the use of aquatic exercise as an effective rehabilitation option, particularly for patients with pain-limited weight-bearing capacity, within musculoskeletal physiotherapy practice.

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AUTHOR's CONTRIBUTION:

Author	Contribution
Muhammad Sarfraz	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision

