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Effect of Retro - Walking Versus Forward – Walking Training Using Underwater Treadmill on Pain and Function in Patients With Knee Osteoarthritis

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Abstract

Background: Knee osteoarthritis (OA) is the predominant arthritic condition, characterized by pain, stiffness, and impaired mobility. Aquatic treadmill training has emerged as an effective adjunct for reducing symptoms and improving function. Aim of the study is to compare the effects of retro-walking and forward-walking on an underwater treadmill in improving pain, function, as well as range of motion (ROM) among patients suffering from chronic knee OA.

Methods: 60 patients from both genders (50 females and 10 male), mild to moderate degrees (grade II, III according to Kellgren and Lawrence classification), unilateral knee osteoarthritis involvement. They were divided into three equal groups; group (A) **(Experimental group A)** forward walking group, group (B) **(Experimental group B)** retro-walking group and group C **(control group)**. The mean age of groups A, B and C were (49.1± 6.45), (45.1± 7.36) and (47.55± 6.03) years respectively, and the mean BMI of groups A, B and C were (27.4 ±2.75), (26.9±2) and (27.69± 2.67) kg/m^2 respectively., Treatment was applied for both groups by the rate of 3 sessions per week for 4 continuous weeks. Outcomes were evaluated at the beginning along with termination of the fourth week using visual analogue scale (VAS) for pain intensity, Functional performance along with functional mobility were measured by 2 -minute walk test and Timed Up and Go (TUG) test, the range of motion was measured by a goniometer and patient function by Western Ontario McMaster Osteoarthritis Index (WOMAC) questionnaire.

Results: Both treadmill groups shown substantial enhancements in pain, function, as well as ROM($p<0.05$) relative to the control group. Retro-walking produced the most substantial reductions in pain as well as functional limitations.

Conclusion: The benefit of adding both forward walking and retro-walking walking under water treadmill training to conventional treatment for KOA in improving pain, function as well as ROM among patients suffering from knee OA.

Trial registration:

The study was registered at ClinicalTrials.gov (NCT06896032). Registration date: 22/02/2025.

INTRODUCTION

Osteoarthritis (OA), often referred to as degenerative joint disease, it is the most common type of arthritis and a major contributor to disability globally. It may arise as primary OA without an identifiable cause, or as secondary OA following trauma, metabolic disorders, or inflammatory insults.

Clinically, OA is characterized by chronic pain, joint stiffness, along with restricted ROM, ultimately impairing daily functional abilities and quality of life. (1)

The knee joint, due to its weight-bearing role, is particularly susceptible, with prevalence rates estimated between 15–40% among individuals aged 40 and rising to over 60% in those above 60 years.

Compounding functional limitations, patients suffering from knee OA frequently experience pain, reduced proprioception, abnormal gait patterns, along with slower walking speeds (2), (3)

Conservative management of knee OA typically involves exercise-based interventions aimed at alleviating pain and improving functional performance. These programs include strengthening exercises, manual therapy, taping, electrotherapy, and hydrotherapy. (4)

Aquatic therapy, in particular, has demonstrated considerable value due to the buoyancy and hydrostatic pressure of water, which reduce joint loading while permitting greater movement. (5)

Among aquatic modalities, underwater treadmill training provides controlled intensity, belt speed, and immersion depth, enabling precise therapeutic adjustment. Previous research highlights its effectiveness in alleviating pain and improving mobility among patients suffering from knee OA (6)

The rehabilitation of knee exercises has progressively transitioned to closed kinetic chain (CKC) exercises, reflecting the growing clinical focus on CKC exercises for functional rehabilitation (7)

Regaining or enhancing the ability to walk is a main objective for patients affected by musculoskeletal or neurological illnesses, including OA, balance disorders, multiple sclerosis, stroke, or cerebral palsy (8), (9), (10)

From a biomechanical point of view, there are two principal reasons why walking in water may be beneficial: lowering of apparent body weight due to buoyancy force leads to reduced gravitational stresses on the musculoskeletal system, while the increased resistance to movement due to fluid drag forces is expected to slow down the motion and enable a patient to regulate their motions consciously (11) (12) (13)

While forward-walking is conventionally applied, retro-walking (backward walking) has been reported to decrease patellofemoral stress and improve neuromuscular control, thereby offering potential added benefits, direct comparisons between forward- and retro-walking in aquatic rehabilitation remain limited. Therefore, this study aimed to assess and contrast the impacts of retro-walking and forward-walking on an underwater treadmill in patients suffering from chronic knee OA, focusing on outcomes of pain, function, and knee ROM.

Materials and Methods

This study was a prospective, single-blind, parallel-group randomized controlled trial conducted in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines, with a completed CONSORT checklist provided as a supplementary file. The study protocol was approved by the Research Ethics Committee of the Faculty of Physical Therapy, Cairo University (P.T.REC/012/005428), and all procedures were performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment. The trial was prospectively registered at ClinicalTrials.gov (NCT06896032) on 22/02/2025. The study ran from February 2025 to June 2025.

Participants:

Sixty participants had been clinically diagnosed with Knee OA for at least three months and were chosen from Outpatient Clinic of International Medical Center (IMC). They were randomly assigned to three equal-sized groups. (GROUP A) Forward walking group (FWG). (GROUP B) Retro walking group (RWG). (GROUP C) conventional physical therapy program (control G) All groups were administered an identical, standardized program of exercise for KOA. **Fig. (1)** They received verbal and written explanations for this study. they signed a consent form which accepted by the faculty of physical therapy at Cairo University, and the International Medical Center (IMC) Ministry of Defense of Egypt. All groups were administered an identical, standardized program of exercise for KOA.

Inclusion criteria

Sixty participants were diagnosed with chronic knee OA.

1. They were between the ages of 40 and 60 of both genders.

2. They had a BMI 25- 35kg/m2.

3. All of them had similar lifestyles unilateral knee osteoarthritis involvement.

4. The degree of osteoarthritis was mild or moderate and have a Kellgren- Lawrence radiographic grade of of1-3 **(14)**

Exclusion criteria:

Participants weren't included if they had:

1. Hydrophobia, pregnancy and psychiatric disorder.

2. cardiac pacemaker, haemorrhagic diathesis and infection.

3. All subjects exhibiting deformities of the hip, knee, and ankle. And recent steroidal or intra articular injections (3 months).

4. any CNS or PNS involvement.

5. systemic inflammatory disease and bone malignancy. **(4)**

Sample size:

A total sample of 60 participants (20 per group) was included. This sample size was considered adequate based on previous similar randomized controlled trials investigating aquatic treadmill interventions in knee osteoarthritis.

Randomization and allocation concealment:

Participants were randomly assigned to three equal groups (n = 20 each) using a computer-generated randomization sequence created with SPSS software (version 23). Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes prepared by an independent researcher not involved in recruitment or assessment. Each participant selected one envelope to determine group assignment.

Blinding:

This study was single-blinded. The outcome assessor was blinded to group allocation, while participants and therapists were not blinded due to the nature of the interventions.

Interventions:

· All participants received a standardized conventional physiotherapy program in addition to group-specific interventions.

· All groups underwent a supervised physiotherapy program three times per week for four weeks, including:

· Transcutaneous electrical nerve stimulation (TENS) for 20 minutes

· Therapeutic ultrasound (1 MHz, 1 W/cm²) applied for 10 minutes

· Exercise program including strengthening, balance, and flexibility exercises

***Study group (A)*:**

Group A of the FWG consisted of twenty individuals who were initially familiarized with the forward walking pattern on flat ground. All participants will practice walking forward in water at lower speeds until they gain confidence with the assistance of hand rails. In addition to more traditional forms of exercise, the prescribed program includes forward walking on an underwater treadmill set at speeds of 1.0 km/hr. for one week and 1.5 km/hr. for the following week. The water level reached the xiphisternum. Participants in group A will engage in a supervised 10-minute forward walking session, accompanied by 5 minutes of warm-up and cool-down periods, three times a week for one month. During the warm-up and cool-down, subjects will execute ankle-toe movements, hamstring and gastrocnemius-soleus stretching, as well as heel raise exercises.

***Study group (B)*:**

Group B of the RWG consisted of twenty individuals who were initially familiarized with the forward walking pattern on flat ground. All participants will practice walking backward in water at minimal speeds until they gain confidence with the assistance of hand rails. The protocol will entail retro-walking on an underwater treadmill at a speed of 1.0 km/hr. for one week, followed by a speed of 1.5 km/hr. for the

subsequent week, combined with traditional exercises. The water level reached the xiphisternum. Participants in group B will engage in a supervised 10-minute forward walking session, accompanied by 5 minutes of warm-up and cool-down activities, three times a week for one month. During the warm-up and cool-down periods, subjects will execute ankle-toe movements, hamstring and gastrocnemius-soleus stretching, as well as heel raise exercises.

***Control group (C)*:**

Twenty participants took part in the study, and the following is the prescribed KOA exercise program, which included nine different exercises for strengthening along with flexibility:

- Warm-up activities: walking at a standard speed on a level ground for 10 minutes, accompanied by easy stretches for the hamstrings and calf.

- Primary exercises for KOA: SLR (Straight leg raise), quadriceps setting, foam squeeze, heel raise, single-leg balance, along with squat.

- stretching exercises: quadriceps as well as hamstring stretching

Outcome measures

Outcome measures were assessed at baseline and after 4 weeks of intervention.

Primary outcome

Pain intensity measured using the Visual Analogue Scale (VAS)

Secondary outcomes

Functional status assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)

Functional mobility assessed using the Timed Up and Go (TUG) test

Walking capacity assessed using the 2-Minute Walk Test (2MWT)

Knee range of motion (ROM) measured using a standard goniometer

***Instrumentation*:**

Evaluative instruments:

***Standard weight and height scale*:**

Before the study started, each participant in all groups had their height and weight measured to determine their BMI.

Visual analogue scale (VAS):

The calibrated 10 cm line, with 0 denoting the absence of pain and 10 representing the most severe pain, was used for assessing each participant's level of pain prior to and following treatment in all groups (A&B &C) **(15).**

***Western Ontario and McMaster University Arthritis Index (WOMAC)*:**

Utilized to evaluate pain, stiffness, along with functional abilities in the participants. It assesses 5 items related to pain, 2 concerning stiffness, and 17 pertaining to functional limitations **(16)**

Timed up-and-go test (TUG):

The Timed Up and Go (TUG) assessment is a performance-based test designed to evaluate functional mobility. During this test, the participant rises from a standard armchair, walks to a designated line on the floor positioned 3 meters away, rotates, returns to the chair, and then sits down. The assessment involves considerable coordination, strength, as well as balance.

The TUG has been employed to assess baseline functional mobility, risk of falling, outcomes of treatment, as well as discharge readiness among community-dwelling older adults, as well as in inpatients and outpatients with a diverse range of diagnoses, such as Parkinson's disease, Alzheimer's disease, lower extremity amputation, arthritis, general deconditioning, cerebellar disorders, as well as stroke **(17).**

2-Minute Walk Test (2MWT) (2 MWT)

The Two-Minute Walk Test (2MWT) is a straightforward, practical, as well as time-conserving assessment. Patients do not experience fatigue. It may serve as an alternative to the 6MWT for patients with KOA who are unable to endure a longer or more intense walking assessment **(18)**

Goniometer:

A goniometer is the most common instrument used to measure a range of motion. The goniometer can simply measure the joint angles. **(19)**

Procedures:

Evaluative procedures:

History taking:

Before the study began, a complete history was obtained from every participant in the all groups, and the information was entered into a data sheet.

Weight and Height measurement:

Before the study started, each participant in all groups had their height and weight assessed after the calibration of the weight-height scale. After taking off all bulky clothing and footwear, each participant was instructed to stand upright in the middle of the scale. The therapist noted the weight on the scale after waiting for the figure to be presented. The therapist placed the scale's ruler squarely on the patient's head, making sure it was level and not tilted. Then, the therapist noted the ruler's top and used a tape measure to quantify the distance from the floor to the head label. The BMI was then computed by dividing the weight in kg by the height in m^2 **(20)**.

Pain intensity measurement:

Each participant's level of pain was identified utilizing VAS in the two groups. Both before and after treatment, every participant was instructed to indicate a point on the scale between two extremes that corresponded to his or her present level of pain **(15).**

Functional performance measurement:

A. The Western Ontario and McMaster Universities Arthritis Index (WOMAC) is extensively utilized in the assessment of hip and knee OA. The questionnaire is self-administered and consists of 24 items divided into three subscales:

- Pain (5 items): while walking, ascending stairs, in a recumbent position, seated or lying down, and in a standing position.
- Stiffness (2 items): upon initial waking and thereafter during the day.
- Physical Function (17 items): utilizing stairs, standing up from a seated position, standing, bending, walking, going into and out of a car, shopping, wearing and removing socks, rising from bed, lying in bed, getting into and out of a bath, sitting, getting on and off the toilet, heavy and light housekeeping tasks.

The test questions are evaluated on a scale of 0 to 4, corresponding to: None (0), Mild (1), Moderate (2), Severe (3), as well as Extreme (4). The scores for each subscale are aggregated, with a potential score range of 0-20 for Pain, 0-8 for Stiffness, as well as 0-68 for Physical Function. A total WOMAC score is obtained by adding the scores of the three subscales; however, alternative techniques of score combination have also been employed. Elevated scores on the WOMAC signify increased pain, stiffness, as well as functional limitations. (Theiler R et al.,2002; Bellamy N et al.,2011; American College of Rheumatology.,2013)

B. The 2-Minute Walk Test (2MWT):

The 2MWT was performed in a well-ventilated, quiet hallway with a hard, flat surface, ensuring a minimum distance of 30 meters. Two cones were positioned 30 meters apart, and the patients would be directed to walk at their own pace to complete the maximum distance within 2 minutes **(17).**

Functional mobility measurement:

TUG test (Time up Go Test) *was* employed to evaluate functional mobility in relation to balance. A firm armchair (seat height of 46 cm) was positioned at one end, while an object was situated at the opposite end, 3 meters away. "Upon hearing the word "go," stand up and safely make your way to the item at the far end of the floor. Walk around it, then return to your chair. **(21)**

Range of motion measurement:

Two physical therapists independently utilized a standard plastic goniometer to assess the knee joint angle in the sagittal plane, utilizing the greater trochanter, the lateral condyle of the femur, the head of the fibula, as well as the lateral malleolus as anatomical landmarks. A roentgenogram of the extremities was obtained prior to the subject's moved. Pearson product-moment correlation coefficients (r) along with interclass correlation coefficients (ICCs) were employed to analyze the data. The data analysis revealed that the interstater reliability (r = .98; ICC = .99) and validity (r = .97–.98; ICC = .98–.99) were high. The results of this study indicate that goniometric measurements of the knee joint are both reliable and valid **(19)**

Treatment procedures:

To ensure their cooperation and confidence throughout the study, every participant in the all groups was given brief and clear instructions regarding the nature of therapeutic activities and their effects, and they signed an informed consent form.

standard physiotherapy training program:

All groups will engage in a supervised standard physiotherapy training protocol at the outpatient physiotherapy department for three days per week over the course of one month, with each session lasting 54 minutes, as documented in a prior study, which involves:

1-The TENS will be conducted by two self-adhesive electrodes positioned on the medial and lateral aspects of the knee joint line. The patients will receive TENS for 20 minutes at a frequency of 100 Hz, with pulse width ranging from 50 to 100 μs and a quadratic biphasic symmetrical pulse shape. The intensity (mA) was calibrated to the personal threshold of a tingling sensation.

2- An applicator with a diameter of 5 cm will be used to apply the US protocol's continuous ultrasonic waves, which have an intensity of 1 W/cm2 and a frequency of 1 MHz The patients were positioned supine, and US was administered to the medial as well as lateral regions of the knee (5

minutes on each side) using circular motions with the probe oriented perpendicularly to maximize energy absorption.

3-An exercise protocol was designed to be easily carried out at home.

All groups were administered an identical, standardized program of exercise for KOA, comprising nine exercises that included muscle strengthening as well as flexibility training as detailed below:

- Warm-up exercises: walking at a usual speed on a level surface for ten minutes, accompanied by gentle stretches for the hamstrings as well as calf.

-Major exercises for KOA: SLR, quadriceps setting, foam squeeze, heel raise, single leg balance, as well as squat.

- stretching exercises: quadriceps and hamstring stretching

The exercises will consist of three sets of ten repetitions, with a three-minute rest interval between each set. **(22)**

Forward-walking program (FWG) group A:

The participants will initially become familiar with the forward walking pattern on level surface. All participants will practice walking forward in water at minimal speeds until they gain sufficient confidence with the assistance of hand railings. Along with standard exercises, the treatment will involve forward walking on an underwater treadmill for one week at a speed of 1.0 km/h and then 1.5 km/h for the following week. The water level reached the xiphisternum.

Group A will walk forward for 10 minutes three times each week for 30 days, with 5 minutes for warmups and cool downs, under supervision. As part of their warm-up and cool-down routines, patients will stretch their hamstrings and gastrocnemius-soleus muscles, as well as heel raises exercises.

(4)

Retro-walking program (RWG) group B:

The participants will initially be familiar with the backward walking method on flat surfaces, ensuring that the toes make contact with the ground prior to the heel during this movement. All participants will practice walking backward in water at minimal speeds until they gain confidence with the assistance of hand rails. Along with regular exercises, the treatment will involve retro-walking on an underwater treadmill for one week at a speed of 1.0 km/h and then 1.5 km/h for the following week. Water levels reached the xiphisternum.

Group B will train three times per week for one month using supervised retro-walking sessions that last 10 minutes and include warm-up and cool-down periods of 5 and 10 minutes, respectively.

As part of their warm-up and cool-down routines, patients will stretch their hamstrings and gastrocnemius-soleus muscles, as well as heel raises exercises **(4)**

Statistical design and data analysis:

The data were presented as mean ± standard deviation, in addition the characteristics of the two groups were compared using chi square and ANOVA. The Shapiro-Wilk test was employed to assess the normality of data distribution. A mixed design MANOVA was conducted to evaluate the effects within and across groups for the measured variables: pain assessed by VAS, function measured by WOMAC, 2MWT, TUG, as well as ROM evaluated with a goniometer. The Statistical Package for the Social Sciences (version 20 for Windows; SPSS Inc., Chicago, Illinois, USA) was utilized for data analysis. $P \leq 0.05$ was deemed significant.

General Characteristics of the Participants:

The mean age of groups A, B and C were (49.1± 6.45), (45.1± 7.36) and (47.55± 6.03) years respectively. The mean weight of groups A, B & C were (73.9± 9.18), (75.15± 8.55) and (76.65± 8.7) kg. The mean height of groups A, B & C were (164.15± 8.78), (166.8± 7.33) and (164.45± 8.13) cm. The mean BMI of groups A, B & C were (27.4 ±2.75), (26.9±2) and (27.69± 2.67) kg/m2 as presented in table (1) and (Fig. 1- 4). ANOVA indicated no substantial differences in mean age, weight, height, along with BMI among the three groups, with $P > 0.05$. The sex distribution of the group A reported that there were 2 (10%) males and 18 (90%) females, of group B were 5 (25%) males and 15 (75%) females and of group C were 3 (15%) males and 17 (85%) females. No substantial difference in sex distribution was observed among the three groups ($p = 0.432$) **table (1)**

Table (1): General characteristics of subjects.

General characteristics	Group A (n=20)	Group B (n=20)	Group C (n=20)	F-value	P-value
Age (years)	49.1± 6.45	45.1± 7.36	47.55± 6.03	1.87	0.167
Weight (kg)	73.9± 9.18	75.15± 8.55	76.65± 8.7	0.488	0.616
Height (cm)	164.15± 8.78	166.8± 7.33	164.45± 8.13	1.51	0.229
BMI (kg/m^2)	27.4 ±2.75	26.9±2	27.69± 2.67	2.68	0.077
Sex (M/F)					0.432
Males, n (%)	2 (10%)	5 (25%)	3(15%)	χ^2 =1.68	
Females, n (%)	18 (90%)	15 (75%)	17 (85%)		

BMI, body mass index; M, males; F, females; P: probability; χ^2, chi square; data are represented as mean ±SD

Results of Univariate analysis of Variance (ANOVA) after 4 weeks: -

Follow-up univariate ANOVAs after 4 weeks reveal that statistically significant difference between groups for pain, F(2,57)= 8.58, p= 0.001, 2 = 0.23, for WOMAC, F(2,57)= 24.18, p= 0.001, 2 = 0.46, for 2MWT, F(2,57)= 4.75, p= 0.012, 2 = 0.14, for TUG, F(2,57)= 11.1, p= 0.001, 2 = 0.28, for knee ROM, F(2,57)= 7.56, p= 0.001, 2 = 0.21

Clinical Characteristics of Subjects after 4 weeks of intervention:

Table (2) presents the clinical characteristics of the participants following a 4-week intervention. The mean and standard deviation (M±SD) of VAS were 4.6±1.57, 3.5±1.32 and 5.6±1.88 cm for Group A, B and C, respectively.

The (M±SD) of WOMAC were 38.55±9.63, 33.5±9.56 and 54.3±10.39 for Group A, B and C, respectively. The (M±SD) of 2MWT were 66.65±12.16, 63.28±11.36 and 56.65±7.08 meters for Group A, B and C, respectively.

The (M±SD) of TUG were 12.11±3.29, 12.08±2.64 and 15.86±2.79 seconds for Group A, B and C respectively. The (M±SD) of knee ROPM were 117.45±10.04, 120.15±6.68 and 110.15±8.18 degrees for Group A, B and C, respectively. The outcomes indicated substantial differences among groups for all assessed variables (P<0.05).

Table (2). Clinical Characteristics of Subjects after 4 weeks of Intervention (N=60)

Variable	Group A	Group B	Group C	F- value	P value	2
VAS (cm)	4.6±1.57	3.5±1.32	5.6±1.88	8.58	0.001	0.23
WOMAC	38.55±9.63	33.5±9.56	54.3±10.39	24.18	0.001	0.46
2MWT (meter)	66.65±12.16	63.28±11.36	56.65±7.08	4.75	0.012	0.14
TUG (seconds)	12.11±3.29	12.08±2.64	15.86±2.79	11.1	0.001	0.28
ROM (degrees)	117.45±10.04	120.15±6.68	110.15±8.18	7.56	0.001	0.21

cm, centimeter; VAS, Visual Analogue Scale; ROM, range of motion; WOMAC, Western Ontario and McMaster Universities Arthritis Index; 2-MWT, 2-Minute Walk Test; TUG, Timed Up and Go; p, probability; 2, partial eta square

Between Groups Effects: table (3)

Pain

There was no statistically substantial difference among the three groups regarding pain prior to treatment (p=0.626). After 4 weeks of intervention, there was no statistically substantial difference among group A as well as group B (p =0.103) where mean difference (MD) and 95% confidence interval (CI) was 1.1(-0.15, 2.35). Also, no statistically substantial difference between group A as well as group C (p =0.160) where MD (95% CI) was -1 (-2.258, 0.25). While, there was statistically substantial difference among group B as well as group C (p =0.001) in favor to group B where MD (95% CI) was -2.1(-3.35,-0.85).

Function

There was no statistically substantial difference among the three groups regarding WOMAC prior to treatment (p=0.317). After 4 weeks of intervention, there was no statistically substantial difference among group A as well as group B (p =0.333) where mean difference (MD) and 95% confidence interval (CI) was 5.05(-2.65, 12.75). While, there was statistically substantial difference among group A as well as group C (p =0.001) in favor to group A where MD (95% CI) was -15.75(-23.45,-8.05). Also, there was statistically substantial difference among group B as well as group C (p =0.001) in favor to group B where MD (95% CI) was -20.8(-28.5,-13.1).

There was no statistically substantial difference among the three groups in 2MWT prior to treatment (p=0.174). After 4 weeks of intervention, there was no statistically substantial difference among group A as well as group B (p =0.933) where mean difference (MD) and 95% CI was -3.38(-4.77, 11.52). Also, there was no statistically substantial difference among group B as well as group C (p =0.149) where MD (95% CI) was 6.63 (-1.52, 14.77). While, there was statistically substantial difference among group A as well as group C (p =0.011) in favor to group A where MD (95% CI) was 10 (1.86, 18.15).

There was no statistically substantial difference among the three groups in TUG prior to treatment (p=0.104). After 4 weeks of intervention, there was no statistically substantial difference among group A as well as group B (p =1) where mean difference (MD) and 95% CI was 0.03(-2.25, 2.3). While, there was statistically substantial difference among group A as well as group C (p =0.024) in favor to group A where MD (95% CI) was -3.76 (-6.03,-1.48). In addition, there was statistically substantial difference among group B as well as group C (p =0.001) in favor to group B where MD (95% CI) was -3.79 (-6.06, -1.5).

Knee ROM

There was no statistically substantial difference among the three groups in knee ROM prior to treatment (p=0.107). After 4 weeks of intervention, there was no statistically substantial difference among group A as well as group B (p =0.944) where mean difference (MD) and 95% CI was -2.7(-9.27, 3.87). While, there was statistically substantial difference among group A as well as group C (p =0.003) in favor to group A where MD (95% CI) was 7.3 (0.74, 13.87). Also, there was statistically substantial difference among group B as well as group C (p=0.001) in favor to group B where MD (95% CI) was 10 (3.44, 16.57).

Table (3). Between Groups Effects after 4 weeks of intervention.

Outcome	Group A versus group B		Group A versus group C		Group B versus group C	
	MD (95% CI)	p-value	MD (95% CI)	p-value	MD (95% CI)	p-value
VAS (cm)	1.1(-0.15,2.35)	0.103	-1 (-2.258,0.25)	0.160	-2.1 (-3.35,-0.85)	0.001
WOMAC	5.05(-2.65,12.75)	0.333	-15.75(-23.45,-8.05)	0.001	-20.8(-28.5,-13.1)	0.001
2 MWT (meter)	-3.38(-4.77,11.52)	0.933	10 (1.86,18.15)	0.011	6.63 (-1.52,14.77)	0.149
TUG (seconds)	0.03(-2.25,2.3)	1	-3.76 (-6.03,-1.48)	0.024	-3.79 (-6.06, -1.5)	0.001
ROM (degrees)	-2.7(-9.27,3.87)	0.944	7.3 (0.74,13.87)	0.003	10 (3.44,16.57)	0.001

cm, centimeter; VAS, Visual Analogue Scale; ROM, range of motion; WOMAC, Western Ontario and McMaster Universities Arthritis Index; 6-MWT, 2-Minute Walk Test; TUG, Timed Up and Go; p, probability; MD, mean difference; CI, confidence interval

Within- Groups Effects table (4):

Group A:

Statistically substantial differences were observed regarding pain where p= 0.001, MD (95% CI) was 3.15 (2.61,3.69), WOMAC where p= 0.001, MD (95% CI) was 23.7 (20.04, 27.36), 2 MWT where p=0.001,

MD (95% CI) was -6.15 (-8.19, -4.1), TUG where p=0.001, MD (95% CI) was 3.23 (2.6, 3.85), and knee ROM where p=0.001, MD (95% CI) was -9.75 (-11.7, -7.79).

Group B:

Statistically substantial differences were observed regarding pain where p= 0.001, MD (95% CI) was 4.5 (3.96, 5.04), WOMAC where p= 0.001, MD (95% CI) was 28.55(24.89,32.2), 2 MWT where p=0.001, MD (95% CI) was -5.95 (-8, -3.9), TUG where p=0.001, MD (95% CI) was 5 (4.38, 5.63), and knee ROM where p=0.001, MD (95% CI) was -8.6(-10.56, -6.64).

Group C:

Statistically substantial differences were observed regarding pain where p= 0.001, MD (95% CI) was 1.95(1.41, 2.49), WOMAC where p= 0.001, MD (95% CI) was 12.25(8.59, 15.9), TUG where p=0.001, MD (95% CI) was 1.69 (1.07, 2.31), and knee ROM where p=0.001, MD (95% CI) was -4.8(-6.76,-2.84). While there were no statistically substantial differences were found in 2 MWT where p=0.068, MD (95% CI) was -1.9 (-3.95, 0.15).

Within-group changes from baseline to after 4 weeks are presented in Table (4).

Table 4. Within group changes from baseline to after 4 weeks of intervention.

Outcome	Change from baseline to 4weeks					
	Group A (n=20)		Group B (n=20)		Group C (n=20)	
	MD (95% CI)	p-value	MD (95% CI)	p-value	MD (95% CI)	p-value
VAS (cm)	3.15 (2.61,3.69)	0.001	4.5 (3.96, 5.04)	0.001	1.95(1.41, 2.49)	0.001
WOMAC	23.7 (20.04, 27.36)	0.001	28.55(24.89,32.2)	0.001	12.25(8.59,15.9)	0.001
2 MWT (meter)	-6.15 (-8.19, -4.1)	0.001	-5.95 (-8, -3.9)	0.001	-1.9 (-3.95,0.15)	0.068
TUG (seconds)	3.23 (2.6, 3.85)	0.001	5 (4.38, 5.63)	0.001	1.69 (1.07, 2.31)	0.001
ROM (degrees)	-9.75 (-11.7, -7.79)	0.001	-8.6(-10.56, -6.64)	0.001	-4.8(-6.76,-2.84)	0.001

cm, centimeter; VAS, Visual Analogue Scale; ROM, range of motion; WOMAC, Western Ontario and McMaster Universities Arthritis Index; 2-MWT, 6-Minute Walk Test; TUG, Timed Up and Go; p, probability; MD, mean difference; CI, confidence interval

Discussion

The aim of this study was to find out and compare the impacts of retro-walking and forward-walking underwater treadmill training on pain, function as well as ROM among subjects suffering from chronic knee OA.

In the current study, sixty subjects from both genders, the unilateral side only was involved. They were divided in to three equal groups: group A (experimental1), group B (experimental 2), group C (control), they had signed a consent form to share in this study which aimed to investigate the effects of retro-walking as well as forward-walking underwater treadmill training on pain, function as well as ROM among subjects suffering from chronic knee OA.

Pain, function, and ROM were evaluated by visual analog scale, TUG test ,2MWT, WOMAC questionnaire respectively twice, first time prior to the beginning of treatment program in addition the second time following 4 weeks of the start of treatment program and manual goniometer.

A primary outcome measure in assessing the efficacy of physical therapy for OA patients is pain reduction.

Pain was decreased in all groups (A& B& C) significantly post treatment with favor to group B (retro–walking under water treadmill training) Pain reduction observed in the retro-walking group may be explained biomechanically by decreased eccentric loading of the quadriceps and reduced compressive forces on the medial knee compartment. Improvements in WOMAC and TUG scores suggest that retro-walking not only alleviates discomfort but also enhances functional independence and mobility, potentially due to greater muscle recruitment and balance control during backward locomotion. These findings support the integration of retro-walking into aquatic rehabilitation protocols for knee OA patients. (6), (23)

Retro-walking on a land treadmill has demonstrated beneficial outcomes among patients having patellofemoral pain as well as during rehabilitation for anterior cruciate ligament injuries (24)

The present study's results concur with those of Riddhi and colleagues, who examined the impact of retro-walking underwater treadmill training on pain, functional performance, as well as mobility among patients with KOA, revealing a significant reduction in VAS scores post-treatment in the retro-walking underwater treadmill training groups (4)

Patients suffering KOA frequently have diminished mobility. TUG scores improved following an acute session of water training compared to land training. These identical results would suggest that balance and neuromuscular components of the body increased more than walking speed as well as step length. The enhancement in functional performance evaluated by WOMAC resulted from the significant influence of retro-walking in augmenting extension moment, hence enhancing strength within the functional range while reducing compression force, which contributes to improved physical function (25)

The present study's findings concur with those of Riddhi and colleagues, who examined the impact of retro-walking underwater treadmill training on pain, functional performance, as well as mobility among

patients with KOA, noting enhancements in mobility as measured by the TUG in addition improvements in functional performance.

The WOMAC assessment was conducted following a brief period of retro-walking on an underwater treadmill (4)

Gondhalekar and Deo postulated that as advantages of retro-walking include improvement in muscle activation pattern, reduction in adductor moment at knee during stance phase of gait and augmented stretch of hamstring muscle groups during the stride; all of these may have helped in reducing disability thus leading to improved function. Retro walking also diminishes the hip flexion moment during the stance phase, so reducing inappropriate stress on the knee joint and, consequently, the associated impairment.

(23) (25) These results align with several previous studies. Naik et al. reported significant pain and functional gains following retro-walking underwater treadmill training among patients having KOA (26). Alghadir and Anwer demonstrated that a 6-week retro-walking protocol produced more significant decreases in pain as well as disability compared to forward-walking or control therapies.

(27). Systematic reviews and experimental studies have similarly highlighted the beneficial impacts of backward walking on proprioception, balance, as well as mobility among KOA populations (28, 29).

Biomechanically, retro-walking may reduce patellofemoral joint stress and alter muscle activation patterns to decrease eccentric quadriceps loading, which can explain the observed reductions in pain and improvements in functional tests such as TUG and WOMAC (30, 31).

Aquatic properties—buoyancy, hydrostatic pressure, and fluid resistance—likely complemented these effects by reducing joint load and enhancing neuromuscular control during gait training (32).

Not all research uniformly favors retro-walking. Some comparative trials have reported equivalent benefits between backward and forward walking, or no clear superiority when multi-modal exercise programs were applied (33), (34).These discrepancies may reflect differences in study design, intervention duration, patient characteristics, immersion depth, or outcome measures.

Although retro-walking demonstrated superior improvements, the lack of statistically significant differences between intervention groups for some outcomes suggests that both modalities are clinically beneficial. These findings highlight that exercise specificity may influence outcomes, but overall aquatic treadmill training remains effective regardless of direction.

Our findings corroborate previous reports that aquatic treadmill training is more effective than land-based exercise alone. The differential improvements between retro- and forward-walking reinforce the clinical utility of diversifying treadmill programs to target specific biomechanical advantages. Nonetheless, the study was limited by its relatively short intervention period (four weeks) and single-center recruitment.

Future trials with larger samples, longer follow-up, and comparative cost-effectiveness analyses are warranted to strengthen clinical recommendations.

This study has several limitations, including the short intervention duration, lack of long-term follow-up, and single-center design, which may limit generalizability. Future research should explore the durability of improvements with extended follow-up, larger and more diverse populations, and the additive effects of combined land- and water-based programs. evaluate combined land- and water-based protocols, and investigate cost-benefit profiles of underwater treadmill training.

Conclusion

Both forward walking and retro-walking walking under water treadmill training could be effective interventions to improve improving pain, function as well as ROM among patients with knee OA, but retro-walking under water treadmill training group had showed better results across most parameters.

Abbreviations

BMI: Body mass index, CKC: Closed kinetic chain, KOA: Knee osteoarthritis, OA: Osteoarthritis, ROM: Range of motion

TENS: Trans cutaneous electrical stimulation, VAS: Visual analogue scale, WOMAC: Western Ontario McMaster Osteoarthritis Index, 2MWT: The 2-Minute Walk Test, TUGT: Timed Up and Go (TUG) test

Declarations

Ethics approval and consent to participate:

The study was approved by the Research Ethics Committee of the Faculty of Physical Therapy, Cairo University (P.T.REC/012/005428). All procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to participation.

Consent for publication:

Not applicable, as the manuscript does not contain any identifiable personal data or images of individual participants. All participants were informed that anonymized data would be used for scientific publication.

Availability of data and materials:

All data generated or analyzed during this study are included in this article. Please contact the corresponding author for access to data presented in this study.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

NA: corresponding author, participated in the study design, participated in the data collection, drafted the manuscript, and finalized the manuscript. NF: participated in the study design, helped with the ethics application and revised the manuscript critically. MA: participated in the study design, participated in the data collection, and revised the manuscript critically.

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Figures

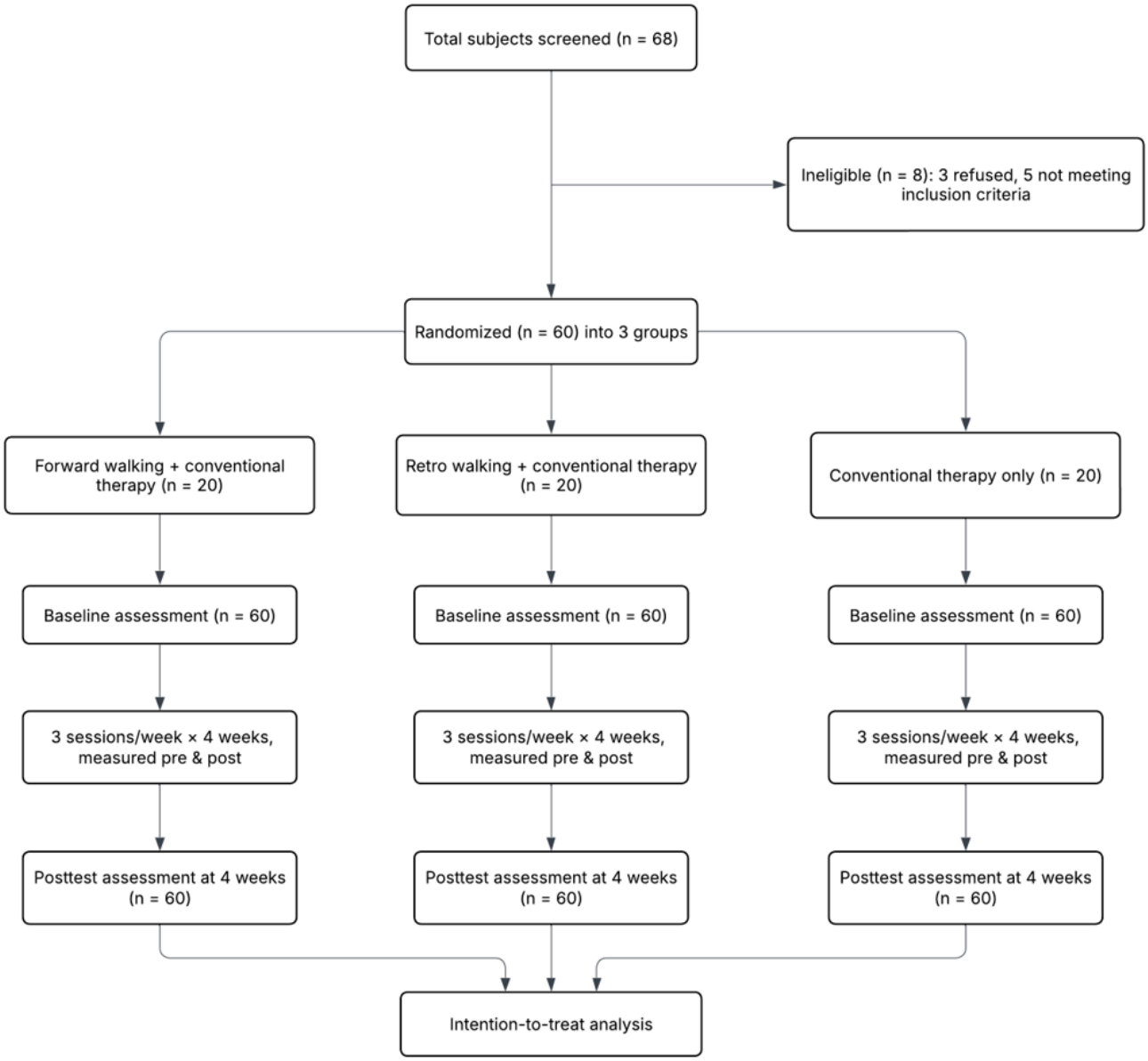


Figure 1

Flow Diagram Randomization and procedure of selection of subjects.

Supplementary Files

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