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## Research article

# Comparison between the efficacy of underwater treadmill and over-ground treadmill training program on knee joint during gait cycle of stroke patients

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## Abstract

**Introduction:** Gait disorder is a common clinical problem for stroke survivors that impacts performance of activities of daily living.

**Objective:** This study was conducted to compare between the efficacy of underwater Treadmill Training Program (TTP) and over-ground (TTP) in improving knee joint Range of Motion (ROM) during the gait cycle of stroke patients.

**Study design:** Randomized control trial.

**Methods:** Forty male patients suffering from post-stroke gait deficits were assigned randomly into two equal groups: study group (A): Received underwater treadmill training program. Control group (B) received over-ground treadmill training program. Patients of both groups were assessed for knee Range of Motion (ROM) during gait cycle using slow motion video and goniometer iPad application. Assessment was done before and after four weeks of treatment for both groups.

**Results:** The comparison between groups post treatment showed a significant increase in knee flexion ROM in initial contact and pre-swing phase and increase in knee extension ROM in mid stance phase of the study group (A) compared with that of control group (B).

**Conclusion:** Under water TTP is more effective than over-ground TTP on improving knee joint ROM during the gait cycle of stroke patients.

## Introduction

Stroke is a leading cause of death and disability worldwide, with an increasing incidence in developing countries [1]. The dynamic of bipedal gait is lost because of neurological injury with disabling consequences. Hemiparetic walking is characterized by a slow and highly inefficient gait, which is a leading cause of disability [2]. Stroke survivors commonly experience circumduction gait with mild to moderate spasticity that limits performance of normal stance and swing phases during the gait cycle. This is characterized by limited ability to perform hip-knee flexion during overground walking.

Today, there is no specific therapeutic program that may enhance gait cycle in stroke survivors. Over-ground walking is commonly associated with poor performance as result of fear of falling. The essential physical properties of water has great therapeutic benefits as it eliminates the gravitational force and so that the only forces that act on the limbs are the muscle torque. Viscosity and hydrostatic pressure are able to support a body, reduce the fear of falling, and encourage balance [3].

The previous studies have found that aquatic therapy can improve muscular strength, endurance, equilibrium ability, and cardiopulmonary endurance because it is less burdensome on the lower limbs. It can provide stable training for those affected with stroke compared with ground exercises and can be helpful for achieving psychological stability [4].

The previous systematic reviews summarized that the water-based exercise for neurological disorder covers a wide variety, including resistance training, movement facilitation, motor control training, balance training, coordination training and other specific techniques indicated that stroke patients improved significantly more in weight shifting ability, dynamic balance, and functional mobility as compared with the land-based intervention [5].

The aim of this study was to investigate the difference between underwater treadmill and over-ground Treadmill Training Program (TTP) in improving knee joint range of motion during the gait cycle of stroke patients.

## Materials and methods

### Participants

The current study was done on forty male patients suffering from post-stroke gait deficits. Inclusion criteria were: stroke patients could walk at least ten meters independently without the help of an assistive instrument, age of 45-60 years, Body Mass Index (BMI) ranged from 22-30kg /m<sup>2</sup>. The participants were excluded if they suffered acute or recurrent stroke, had shortening or contracture in lower limb flexors, moderate or severe spasticity as defined as modified Ashworth scale equal or greater than grade three, any cognitive or psychiatric disorders or other neurological diseases which would affect the results of this study and chronic neglected patients.

### Interventions

Forty male patients with post-stroke gait deficits were

included in the current study. The patients were recruited from local hospital and randomly divided evenly into two groups of twenty patients: study group A and control group B. Randomization was performed at 1:1 ratio considering the order of enrollment in the trial without considering their modified Ashworth scale scores.

Before enrollment, all participants were asked to read and sign a consent form that was approved by local ethical committee. Study group A. The patients received underwater treadmill training program in a therapy pool with a water depth adjusted to the chest level (Xiphoid process) by using movable floor pool [6]. The temperature of the water was adjusted to 34°C-36°C with an air temperature of 24°C, the program consisted of five minutes warm up-period followed by 30 minutes of strengthening, trunk mobility and balance exercises and 15 minutes aquatic treadmill training (Begin at an individual's comfortable turning speed on level ground, increased by increments of 0.05 m/s every 5 minutes as tolerated), finally ten minutes Cool-down period. Control group B. The patients received over-ground treadmill training program consisted of five minutes warm up-period followed by 30minutes of strengthening, trunk mobility and balance exercises and 15minutes over-ground treadmill training (Begin at an individual's comfortable turning speed on level ground, increased by increments of 0.05 m/s every 5 minutes as tolerated), finally ten minutes Cooling-down period [7].

### Outcome measures

All assessment methods were valid and reliable. All patients were passed into the following assessment: (I) knee joint (ROM) during the gait cycle: by using slow motion video and goniometer iPad application: The iPhone 6 plus camera adjusted to view the whole markers in sagittal plane, captured knee flexion and extension from lateral view during the gait cycle [8]. The video was taken while the patient walks on over-ground treadmill. The range of motion detected over the screen shoot by using iPad goniometer application [9].

### Statistical analysis

Descriptive statistics and unpaired t-tests were conducted for comparison of age between both groups. Normal distribution of data was checked using the Shapiro-Wilk test for all variables. Levene's test for homogeneity of variances was conducted to test the homogeneity of knee ROM between the study and control groups. Unpaired t-test was conducted for comparison of knee ROM between the study and control group. Paired t-test was conducted for comparison between pre and post treatment in each group.

The level of significance for all statistical tests was set at  $p < 0.05$ . All statistical analysis was conducted through the Statistical Package for Social Studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA). The significance or alpha ( $\alpha$ ) level of the study was set to 0.05 (5%) [10]. Statistical significance was set at the ( $p < 0.05$ ) level of probability [11].

### Ethical statement

The research protocol has followed the tenets of the



declaration of Helsinki, and has been approved by the Ethical Committees of faculty of physical therapy, Cairo University NO.P.T.REC/012/002182.

## Results

### Basic characteristics of the patients

Subject characteristics were demonstrated in Table 1. There was no significant difference between groups in age, weight, height, BMI and duration of illness ( $p > 0.05$ ).

### Effect of treatment on knee joint ROM in initial contact, mid stance and pre swing

**Within group comparison:** There was a significant increase in knee flexion in initial contact and knee flexion in pre swing post treatment compared with that pre-treatment in the study group ( $p > 0.001$ ). Also, there was a significant increase in knee extension in mid stance post treatment compared with that pre-treatment in the study group ( $p > 0.001$ ). While there was no significant change in knee ROM in the control group between pre and post treatment ( $p > 0.05$ ) (Table 2).

**Between two-group comparison:** There was no significant difference between groups pretreatment ( $p > 0.05$ ). Comparison between groups post treatment showed a significant increase in knee flexion in initial contact and pre swing and significant increase in knee extension in mid stance of the study group compared with that of control group ( $p < 0.05$ ) (Table 2).

## Discussion

The major findings of the current study highlighted that under water TTP results increasing knee flexion and extension ROM compared to overground TTP in survivors with stroke.

Post treatment results, showed a significant a significant increase in knee flexion in initial contact and pre swing and significant increase in knee extension in mid stance of the study group (A) compared with that of control group (B).

The results are consistent with the results of [12], summarized that the water-based exercise, for stroke patients, showed more significant improvement in weight shifting ability, dynamic balance, and functional mobility as compared with the land-based intervention. Moreover [13], concluded that hydrotherapy exhibited significant effects on improving postural balance in chronic stroke patients than in sub-acute patients with stroke and showed improvement in paretic knee extensor strength.

**Table 2:** Show the mean of knee ROM in initial contact, mid-stance and pre-swing pre and post treatment of the study and control groups.

	Study group	Control group	MD	t-value	p value
	$\bar{x} \pm SD$	$\bar{x} \pm SD$			
Knee flexion in initial contact (degrees)					
Pre treatment	6.34±1.53	6.94±1.8	-0.6	-1.13	0.26
Post treatment	8.41±2.84	6.47±2.35	1.94	2.35	0.02
MD	-2.07	0.47			
t-value	-3.97	0.78			
	$p = 0.001$	$p = 0.44$			
Knee extension in mid stance (degrees)					
Pre treatment	8.1±3.01	7.21±2.86	0.89	0.95	0.34
Post treatment	5.01±1.92	6.92±2.76	-1.91	-2.54	0.01
MD	3.09	0.29			
t-value	7.66	1.6			
	$p = 0.001$	$p = 0.12$			
Knee flexion pre swing (degrees)					
Pre treatment	38.63±8.85	39.27±7.28	-0.64	-0.25	0.8
Post treatment	45.65±7.1	40.51±7.53	5.14	2.22	0.03
MD	-7.02	-1.24			
t-value	-5.33	-1.7			
	$p = 0.001$	$p = 0.1$			

SD: Standard Deviation; MD: Mean Difference; p-value: probability value

The water environment serves as a partial support for the body, allowing for mobilization of joints. Also, aquatic therapy provides motor and sensory stimuli that can potentially improve balance and muscle function [14]. Furthermore, the buoyancy of water might allow stroke patients to move with less effort and across movement planes that would be difficult during overground gait training without assistance [15].

The results are consistent with previous work [16] confirming that aquatic training in stroke patients significantly improves motor functions. These improvements can be attributed to the water environment, which partially supports the body, thus facilitating whole body movements.

Water is a fluid medium, with medium density and viscosity, which reduces the speed of movement, and because of this, when an individual enters a pool with water at waist level, approximately 50% of the weight is reduced, in addition to reducing gravity, in water, the probability of falling decreases by 21%–23%. This means that people experience greater mobility in water with greater range of motion [17].

These results are in agreement with [18], proved that four weeks of aquatic trunk exercise could improve the gait factors significantly in terms of walking speeds, walking cycles, affected-side stance phases, affected-stride lengths, improvement in weight shifting ability and stance-phase symmetry indices, respectively.

The results are in agreement with [19], proposed that

**Table 1:** Show the basic characteristics of participants.

	Group A (n=20)	Group B (n=20)	p-value
	Mean±SD	Mean±SD	
Age (years)	54.2±6.29	52.45±6.19	0.38
Weight (kg)	81.35±9.83	80.4±8.27	0.74
Height (cm)	168.6±5.27	170.3±5.12	0.3
BMI (kg/m <sup>2</sup> )	28.58±2.84	27.75±3	0.37
Duration of illness (months)	8.33±2.35	8.66±1.95	0.54

SD: Standard Deviation; p-value: Probability value



underwater treadmill gait training resulted in significant improvements in the stance phase of the lower extremity on the affected side, weight support, and psychological stability compared to out-of-water treadmill gait training.

These results are in agreement with [20], evaluated the effect of an aquatic therapy program designed to increase balance in stroke survivors. The results demonstrated that the aquatic therapy was beneficial in improving balance and the strength of the hemi-paretic leg in stroke survivors, despite any neurologically stable chronic conditions after stroke.

### Limitations

1) Individual differences between patients in consideration to their effort during assessment and treatment outcomes. 2) Psychological status and cooperation of the patients might affect the results of the current study. 4) The study was limited to men. 5) The current trial is considered an open-labeled randomized trial; however, future clinical trials should consider block randomization after considering the Modified Ashworth Scale scores with emphasis on ankle dorsi / plantar flexion range of motion. Also, the inclusion criteria should have been based on Brunnstrom stages of stroke recovery.

### Conclusion

The results of this study concluded that underwater treadmill training program is more effective than over-ground treadmill training program on improving knee joint stability and mobility during the gait cycle which could improve gait kinematic and allow more weight shifting ability and stance-phase symmetry on paretic limb in stroke patients.

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