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RESEARCH ARTICLE

Effect Of Aquatic Therapy On Bilateral Prowling And Proprioceptive Training On Knee Hyperextension In Post Stroke Patients

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ABSTRACT:- ***Background:*** Stroke is a leading cause of long-term disability worldwide. A common gait abnormality in stroke survivors is knee hyperextension (genu recurvatum), primarily resulting from impaired proprioception, muscle weakness, and poor neuromuscular control. This condition can compromise gait efficiency and increase fall and joint injury risks. ***Objective:*** This study aimed to evaluate the effectiveness of aquatic proprioceptive training combined with bilateral prowling in reducing knee hyperextension and improving gait in post-stroke individuals. ***Methods:*** 28 post-stroke individuals were randomly assigned to two groups. Group A (n=14) received conventional physiotherapy with land-based proprioceptive training and bilateral prowling. Group B (n=14) followed the similar conventional protocol but performed proprioceptive training and bilateral prowling in an aquatic setting. Outcomes were measured at baseline, and at 2nd, 4th, and 6th weeks using the Wisconsin Gait Scale and Kinovea software. ***Results:*** Both groups showed significant improvements over six weeks. Group A shows WGS scores decreased from 27.2 to 21.1 and knee hyperextension improved from -13.6˚ to -10.3˚ ($p = 0.002$). Group B showed greater improvements, with WGS scores reducing from 27.9 to 19.4 and knee angles from -14.0˚ to -8.4˚ ($p = 0.0001$). Between-group analysis revealed significantly better outcomes in Group B, supporting the effectiveness of the aquatic-based intervention. ***Conclusion:*** Aquatic-based proprioceptive and prowling training is more effective than land-based therapy in reducing knee hyperextension and improving gait in post-stroke rehabilitation.

Keywords: Stroke, knee hyperextension, proprioceptive training, aquatic therapy, prowling.

INTRODUCTION

Stroke remains a major global health challenge and is recognized as one of the leading causes of long-term disability and mortality worldwide [1]. It is defined as an acute neurological event resulting from an interruption or significant reduction in cerebral blood flow, leading to deprivation of oxygen and essential nutrients to brain tissue. This disruption can occur due to either ischemic events, characterized by arterial occlusion, or haemorrhagic events, involving the rupture of cerebral blood vessels [2].

Stroke can be broadly classified into two primary categories based on its underlying pathophysiological mechanisms i: e ischemic stroke and haemorrhagic stroke. Haemorrhagic stroke arises from the rupture of weakened or damaged blood vessels, resulting in the extravasation of blood into the surrounding brain tissue or subarachnoid space. This type of stroke is less common, with an incidence rate of approximately 15–20% but it is often associated with more severe outcomes. However, Ischemic stroke is the most prevalent form, accounting for approximately 80% of all stroke cases. It occurs due to the occlusion or significant narrowing of a major cerebral artery, leading to a reduction or complete cessation of blood flow to the affected region of the brain. The obstruction either can occur due to a thrombus formation or an embolus that travels and blocks an artery resulting in deprivation of brain tissue from essential oxygen and nutrients ultimately triggering a cascade of cellular injury and neuronal death [3]. Both types of stroke present significant clinical challenges and require distinct diagnostic and therapeutic approaches. With haemorrhagic stroke certainly requiring surgical intervention to evacuate hematomas or repair the ruptured vessels. While ischemic strokes often necessitate urgent reperfusion therapies, such as thrombolysis or mechanical thrombectomy. Thus, early diagnosis and prompt medical intervention are critical for minimizing neurological damage, improving functional outcomes, and reducing mortality rates associated with both stroke types [4].

The annual cumulative incidence of stroke in India is estimated to range between 105 to 152 cases per 100,000 individuals, indicating a substantial burden on the nation’s healthcare system and highlighting the pressing need for preventive strategies and effective management protocols. Moreover, the crude prevalence of stroke across various regions of the country over the past decade has demonstrated considerable variability, with figures ranging from 44.29 to 559 cases per 100,000 individuals [5].

Following a stroke, individuals often present with impairments in sensory, motor, cognitive, perceptual, and language functions, along with alterations in the level of consciousness. These deficits arise due to the localized damage to specific regions of the brain, depending on the vascular territory affected [2]. They also often develop a pathological gait pattern due to several distinct abnormalities. This altered gait is typically marked by reduced walking speed, asymmetrical movement patterns, decreased step length, and compromised control over the hip, knee, and ankle joints. These gait deviations result from the loss of motor control, muscle weakness, and spasticity [6]. Among the various gait abnormalities observed most frequently reported is knee hyperextension, also known as genu recurvatum, is particularly prevalent among stroke survivors, affecting approximately 65% of individuals post stroke [7]. This gait abnormality compromises gait dynamics and impacts both stability and fluidity of movement. This results from factors such as quadriceps weakness, plantar flexor spasticity, proprioceptive deficits, or compensatory strategies adopted to enhance stability [8]. This impairment increases the risk of tripping and falls, further limiting mobility and independence. Additionally, the repetitive stress caused by hyperextension can also lead to joint pain, ligament strain, and long-term degenerative changes in the knee joint [9].

A variety of therapeutic strategies have been developed to address this gait commonly observed in stroke survivors. Among these, interventions such as neuromuscular electrical stimulation (NMES), robotic-assisted gait training devices, body supported treadmill training and orthotic devices have demonstrated efficacy in promoting gait recovery by enhancing muscle strength, improving motor control, and facilitating more coordinated movement patterns [10]. However, recent research highlighted the beneficial effectiveness of proprioceptive training combined with prowling exercises as part of a comprehensive physical therapy regimen in addressing knee hyperextension among individuals recovering from a stroke [11].

Proprioceptive training focuses on enhancing the body's ability to sense joint position, movement, and balance—functions often impaired following a stroke due to neuromuscular dysfunction and sensory deficits. Prowling involves walking with bilateral knee flexion maintained between 15 to 45 degrees throughout the stance phase. By sustaining a flexed knee position during walking, prowling exercises aim to prevent the knee from extending beyond its normal range, thereby reducing the tendency for knee hyperextension and also it encourages continuous activation of the quadriceps, hamstrings, and calf muscles, promoting muscle strength and endurance around the knee joint [11].

Also, few literatures support the fact that various unique properties of hydrotherapy can significantly aid recovery by improving mobility, balance, and strength while reducing joint stress. The buoyancy of water reduces the body's effective weight, facilitating movement and decreasing the risk of injury during exercises. Additionally, the resistance provided by water enhances muscle strengthening and cardiovascular endurance [12]. The hydrostatic pressure exerted by water immersion contributes to improved proprioceptive feedback and circulatory dynamics, which are vital for restoring balance and coordination post-stroke. Additionally, the thermal properties of water can induce muscle relaxation, reduce spasticity, and alleviate pain, creating an optimal environment for neuromuscular re-education [13].

Thus, the current study focuses on combining the effect of proprioceptive training with bilateral prowling exercises in aquatic therapy to observe if this could offer a comprehensive strategy to mitigate abnormal knee hyperextension during gait in post-stroke patients.

MATERIALS AND METHODS

The experimental study was approved by the Ethics Committee of Krishna Vishwa Vidyapeeth, KIMSDU. (Protocol no. 026/2023-2024). A total of 30 subjects were allotted in the study based on the eligibility criteria. Among the 30 participants only 28 participants completed the protocol session with 2 participants being dropped out as they discontinued the session. The participants were divided by simple random sampling method into experimental and control group with 14 in each group.

Table no 1- Inclusion and exclusion criteria were:

INCLUSION CRITERIA	EXCLUSION CRITERIA
Subjects of both sexes with age between 35-65 years	Lower Limb having Modified Ashworth Scale score ≥3
Clinically confirmed diagnosis of stroke (ischemic or hemorrhagic) with residual motor impairment	Musculoskeletal Disorders such as osteoarthritis, joint deformities, or history of lower limb fractures that may affect gait.
Presence of knee hyperextension examined through assessment	Uncontrolled cardiovascular and respiratory conditions
Brunstorm recovery stage of affected extremity> 3	Open wounds, skin infections, urinary or fecal incontinence, severe fear of water.
Individuals least 3 months post-stroke	History of Recent Surgery of lower limb
Ability to walk 5m with/without support	Severe Cognitive Impairment
MMSE score>/=23	Participation in Other Rehabilitation programs that may affect study outcomes

PROCEDURE

The study was conducted from 2023-2024 in the OPD setting of Krishna College of Physiotherapy. The participants selected were given a brief idea about the study protocol and consent from each participant was obtained. They were then assessed pre, 2nd week, 4thweek, and 6th week post the session using the outcome measures like Wisconsin gait scale and kinovea software. The participants were assigned into two groups based on the simple randomization technique. Group A (control group) received baseline conventional physiotherapy sessions and performed additional bilateral prowling and proprioceptive training exercises on land. While Group B (experimental group) performed the similar baseline intervention along with bilateral prowling and proprioceptive training exercise in the aquatic environment.

OUTCOME MEASURES

Wisconsin Gait Scale (WGS): It is an observational tool designed to assess gait quality in individuals' post-stroke, particularly those with hemiplegia. Renowned for its validity, reliability, and ease of use, the WGS enables clinicians to monitor progress in gait rehabilitation effectively. It encompasses 14 observable parameters divided into four subscales corresponding to specific gait phases: stance phase, toe-off, swing phase, and heel strike. During the stance phase of the affected leg, five parameters are evaluated. The toe-off phase includes two parameters. The swing phase comprises six parameters. And the heel strike phase includes one parameter only. Each parameter is scored, and the total score of 42 points, with higher scores indicating poorer gait performance and greater deviations from normal gait patterns. The WGS's comprehensive approach allows clinicians to identify specific gait abnormalities, facilitating targeted interventions in rehabilitation programs.

Kinovea Software: Kinovea is a two-dimensional (2D) motion analysis software commonly used in clinical and research settings to assess human movement. It enables precise, frame-by-frame video analysis and provides quantitative data on joint kinematics, spatiotemporal gait parameters, and range of motion. Although Kinovea operates in 2D, studies have demonstrated its high intra- and inter-rater reliability and good validity. It serves as a cost-effective and accessible tool for functional movement analysis.

EXERCISE INTERVENTION

Control Group

The control group included 14 participants that performed bilateral prowling and proprioceptive training on land. All were assessed Pre, 2nd week, 4thweek, and 6th week post the session using the Wisconsin gait scale and kinovea software. Being a 6 weeks protocol it was divided into 1-3 weeks and 4-6 weeks. For 1-3 weeks the participant performed proprioceptive training such as single limb stance, squats, dynamic squats, marching, lunges and single limb squats with 10 repetitions 1 set for each intervention. Also, additional 5 rounds of bilateral prowling that involves walking with flexed knee of 15-20 degrees was performed by the participant. As the week progresses for 4-6 weeks the participant performed similar proprioceptive training with increases in repetitions that is 20 reps for the same and 10 rounds of bilateral prowling.

Fig no 1- Single leg stance on land

Fig no 3- Squats on land

Fig no 2- Prowling on land

Fig no- 4 Lunges on land

Experimental Group

The experimental group also included 14 participants who performed bilateral prowling and proprioceptive training in aquatic therapy. These participants were also Pré, 2^{nd} week, 4^{th}week, and 6^{th} week post the session using the Wisconsin gait scale and kinovea software. Being a 6 weeks protocol it was divided into 1-3 weeks and 4-6 weeks. For 1-3 weeks the participant performed proprioceptive training such as single limb stance, squats, dynamic squats, marching, lunges and single limb squats with 10 repetitions 1 set for each intervention. Also, additional 5 rounds of bilateral prowling that involves walking with flexed knee of 15-20 degrees was performed by the participant. As the week progresses for 4-6 weeks the participant performed similar proprioceptive training with an increase in repetitions that is 20 reps for same and 10 rounds of bilateral prowling in an aquatic setting.

Fig no 5- lunges in aquatic pool

Fig no 6- Prowling in aquatic pool

Fig no 7- Single leg stance in aquatic pool

Fig no 8- Squats in aquatic pool

STATISTICAL ANALYSIS

The sample size was calculated using the formula $n= Z^2pq/L^2$. A total of 28 participants completed the entire 6 weeks protocol duration. 14 each in a control and experimental group. The statistical analysis was calculated using the SPSS software. Repeated ANNOVA test was used to assess the post outcome difference visible over the weeks. While the unpaired-t-test was used to assess the same between the groups.

RESULTS

The **(Table 2)** shows the gender distribution in the study which totals to 28 patients. While (**Table 3)** shows the age distribution of the enrolled patients from age group of 35 to 65. For within group analysis the mean value of Wisconsin gait scale of group A **(Table 4 and Graph 1**) on-1st day, 2nd week, 4th week, 6th week showed a p value of 0.002 which is significant. The mean value of Kinovea software of group A that analysed the joint kinematics on the **(Table 5 and Graph 2)** 1st day, 2nd week, 4th week, 6th week showed a p value of 0.002 which indicated clinical significance. For group B the mean value of Wisconsin gait scale **(Table 6 and Graph 3) on**-1st day, 2nd week, 4th week, 6th week showed a p value of 0.0001 which indicates extreme significance. Also, **(Table 7 and Graph 4)** shows the mean value of Kinovea software of group B that analysed the joint kinematics for 1st day, 2nd week, 4th week, 6th week showed a p value of 0.0001 which indicated higher clinical significance. For between group analysis the **(Table 8 and Graph 5)** showed the pre and post mean values between experimental group and control group for Wisconsin gait scale. There was a statistically significant difference in terms of p value among both the groups. However, clinically in terms of mean group B the experimental group shows more marked improvement post assessment than group A the control group. For the pre and post mean value between experimental group and control group for kinovea software **(Table 9 and Graph 6)**. The p value showing a high level of significance statistically between both groups and marked clinical difference was observed in terms of mean in group B the experimental group than group A the control group.

Table 2- Gender distribution in the study

Gender	No of patients
Male	26
Female	2
Total	28

Table no 3-Age distribution in the study

Age groups	No of patients
35-45	12
46-55	6
56-65	10
Total	28

WITHIN GROUP ANALYSIS

Table no 4- Wisconsin Gait Scale for Group A for 1st day, 2nd week, 4th week, 6th week

Wisconsin Gait Scale	Pre 1 day	2 weeks	4 weeks	6 weeks	F- value	P-value
Group A	27.2 ±2.4	25.0± 2.2	24.1±2.3	21.1±1.4	28.4	0.002

Graph 1- Wisconsin Gait Scale for Group A for 1st day, 2nd week, 4th week, 6th week

Table no 5- Kinovea Software for Group A for 1st day, 2nd week, 4th week, 6th week

Kinovea Software	Pre 1st day	2nd weeks	4th weeks	6th weeks	F- value	p- value
Group A	-13.6± 0.8	-12.8± 0.9	-11.9± 0.9	-10.3± 0.7	59.1	0.002

Graph 2- Kinovea Software for Group A for 1st day, 2nd week, 4th week, 6th week

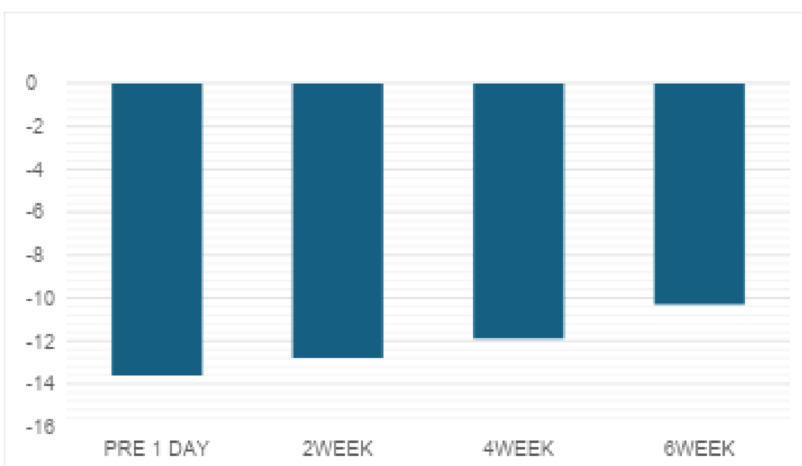


Table no 6- Wisconsin Gait Scale for Group B for 1st day, 2nd week, 4th week, 6th week

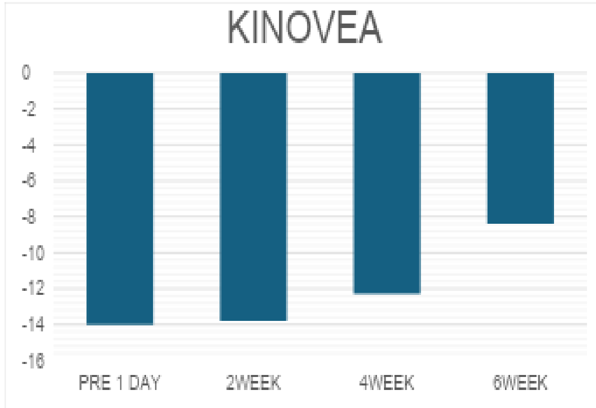
Wisconsin Gait Scale	Pre 1st day	2nd weeks	4th weeks	6th weeks	F- value	P value
Mean	27.9 ±4.5	25.6±4.4	22.6± 4	19.4± 3	96.5	0.0001

Graph 3- Wisconsin Gait Scale for Group B for 1st day, 2nd week, 4th week, 6th week

Kinovea Software	Pre 1st day	2 weeks	4 weeks	6 weeks	F-value	P- value
Mean	-14.0± 1.2	-13.8 ±1.3	-12.3± 1.3	-8.4± 1.5	285.4	0.0001

Table 7- Kinovea Software for Group A for 1st day, 2nd week, 4th week, 6th week

Graph 4- Kinovea Software for Group A for 1st day, 2nd week, 4th week, 6th week



BETWEEN GROUP ANALYSIS

Table 8- Wisconsin Gait Scale analysis between pre and post mean of group A and group B

Wisconsin Gait Scale	Pre	Post	F- value	t- value	p-value
Group A	27.2 ±2.4	21.1±1.4	3.9	2.27	0.0001
Group B	27.9±4.5	19.4± 3			

Graph 5- Wisconsin Gait Scale analysis between pre and post mean of group A and group B

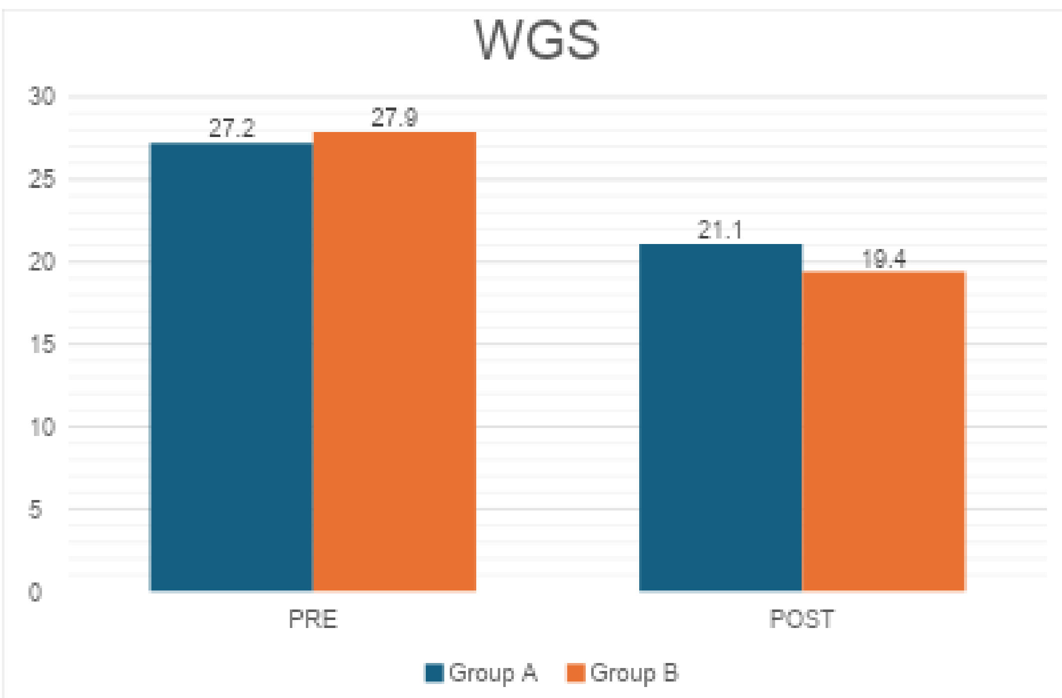
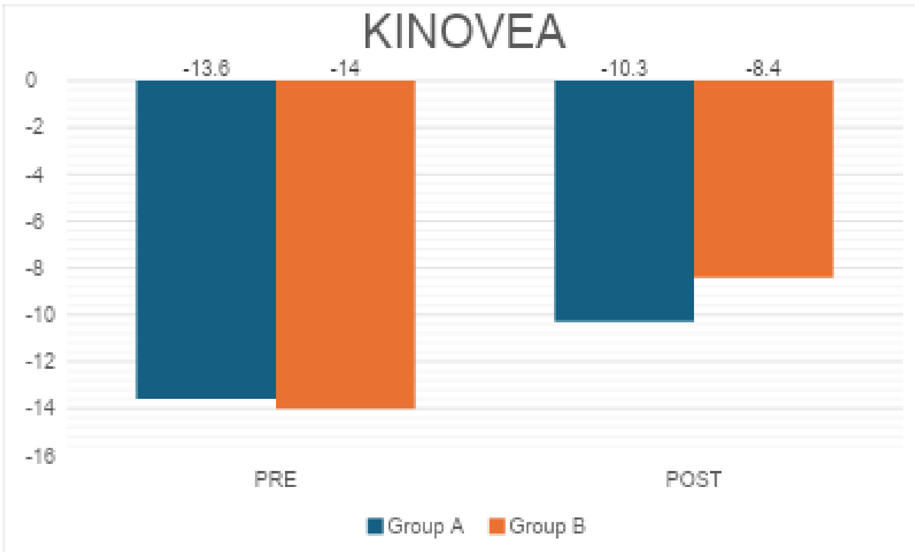


Table 9- Kinovea Software analysis between pre and post mean of group A and group B

Kinovea Software	Pre	Post	F- value	t- value	p-value
Group A	-13.6± 0.8	-10.3± 0.7	4.5	3.5	0.0001
Group B	-14.0± 1.2	-8.4± 1.5			

Graph 6- Kinovea Software analysis between pre and post mean of group A and group B



DISCUSSION

The present study aimed to evaluate the effectiveness of aquatic proprioceptive training combined with bilateral prowling exercises on knee hyperextension among post-stroke individuals. Knee hyperextension, or genu recurvatum, is a frequently encountered gait deviation in post-stroke individuals, often resulting from a constellation of neuromuscular impairments including weakness, spasticity or diminished proprioceptive acuity.

In the present study, we assessed the efficacy of a structured aquatic therapy protocol that combined bilateral prowling—a gait retraining technique promoting a sustained flexed knee posture—with proprioceptive training to address knee hyperextension in stroke survivors. In this study, Group B consisted of 14 individuals who underwent 15-20 mins of additional proprioceptive training combined with bilateral prowling in an aquatic environment. while Group A also comprised 14 individuals who received the same intervention for the same period of time but performed on land. Both groups performed the similar conventional intervention as a baseline prior to proprioceptive training and bilateral prowling. Importantly, participants of both sexes were included to ensure a representative sample and enhance the generalizability of the findings. The outcomes were assessed using the Wisconsin Gait Scale (WGS) and Kinovea software, recorded weekly over a six-week intervention period. At baseline, both groups exhibited significant gait impairment and pathological knee hyperextension. The mean Wisconsin Gait Scale (WGS) scores were 27.2 in Group A and 27.9 in Group B, reflecting poor dynamic stability and gait efficiency. Similarly, Kinovea software analysis revealed abnormal knee angles of -13.6° in Group A and -14.0° in Group B, indicating substantial hyperextension during stance phase.

After two weeks of intervention, both groups demonstrated early improvements in gait function and knee joint kinematics. Group A, which underwent land based proprioceptive training combined with bilateral prowling, exhibited significant improvements in gait function (WGS: 27.2 to 25.0) and knee biomechanics (Kinovea: -

13.6° to -12.8°). However, Group B, who received proprioception training combined with bilateral prowling in the aquatic environment, demonstrated even greater improvements (WGS: 27.9 to 25.6; Kinovea: -14.0° to -13.8°). By the fourth week, more significant clinical progress was observed. Group A's WGS decreased to 24.1 and the knee hyperextension angle improved to -11.9°, while Group B showed further advancement with a WGS of 22.6 and Kinovea reading of -12.3. And at the end of the six-week intervention period, both groups exhibited statistically significant improvements. Group A achieved a WGS of 21.1 and a knee angle of -10.3°, while Group B demonstrated greater improvements with a WGS of 19.4 and a markedly reduced knee hyperextension angle of -8.4 However, both groups show extremely significant values in terms of p value but, clinically in terms of mean group B the experimental showed superiority over the group A. Thus, the superiority observed in the group B supports literatures that highlighted the superiority of hydrotherapy over conventional therapy in restoring gait parameters due to the permissive properties of water, which facilitate high-repetition, low-impact motor training [14-15]. The various properties of water provide advantages such as buoyancy which reduces gravitational loading, enabling individuals with impaired strength and joint instability to engage in dynamic movements that would be otherwise difficult or unsafe on land. Additionally, the hydrostatic pressure and viscosity inherent to aquatic mediums provide continuous somatosensory input and multidirectional resistance, which are critical for proprioceptive enhancement and sensorimotor retraining [16]. While continuous proprioceptive stimulation provided by water may have contributed to the reorganization of somatosensory maps in the central nervous system, thereby enhancing joint position sense and reducing hyperextension tendencies during gait [17]. Also, Bilateral prowling, performed in an aquatic environment, encourages activation of the hamstrings and other posterior chain muscles, promoting knee flexion during the stance phase of gait. When combined with the enhanced sensory feedback provided by water, this can facilitate the retraining of motor patterns and improve joint stability [17].

Thus, the initial two weeks of intervention in the aquatic medium led to executing knee control during gait without compensatory strategies. By four weeks of intervention the various properties of water played a vital role as buoyancy and hydrostatic pressure inherent to water immersion provides continuous sensory input to cutaneous and deep proprioceptors that improved postural alignment and dynamic joint stabilization, further supporting the retention of a flexed knee position during ambulation. By six weeks of intervention, graded resistance provided by water promotes efficient co-contraction of quadriceps and hamstring muscle groups, both of which play a pivotal role in maintaining dynamic knee stability thus facilitating improved joint alignment and functional control throughout the gait cycle [18]. Additionally on land, stroke survivors often exhibit fear of falling, which may inhibit movement exploration and limit engagement. In contrast, the supportive properties of water mitigate these fears and encourage fuller range of motion and participation, critical for neuroplasticity and motor recovery [19].

Thus, the findings of the present study lend strong support to the research alternate hypothesis, demonstrating that the integration of aquatic-based proprioceptive exercises and bilateral prowling gait training yields a significant therapeutic effect in reducing knee hyperextension among individuals recovering from stroke.

CONCLUSION

The present study concluded with achieving positive gains in reducing knee hyperextension among post stroke individuals by performing bilateral prowling and proprioceptive training in aquatic environment.

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CONFLICTS OF INTEREST STATEMENT

The authors state that there are no personal relationships or competing financial interest that could have hampered the work reported.

DATA SHARING STATEMENT

All the data in the present article have been included and analysed during the study procedure.

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