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Immediate Effects of Mulligan Mobilization on Ankle Proprioception, Dorsiflexion Range of motion and Balance in individuals with Chronic Hemiparetic Stroke: A Quasi-Experimental study

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Abstract

Background and Objectives : Balance deficits and reduced mobility are common following chronic hemiparetic stroke and may be associated with impaired ankle proprioception and limited dorsiflexion range of motion. Mulligan Mobilisation with Movement is a manual therapy technique designed to improve joint mechanics and sensorimotor function; however, evidence regarding its immediate effects remains limited. Therefore, this study aimed to evaluate the immediate effects of ankle Mulligan Mobilisation with Movement on ankle proprioception, dorsiflexion range of motion, balance, and functional mobility in individuals with chronic hemiparetic stroke..

Methods: A one-group pretest–posttest quasi-experimental study was conducted in the Physiotherapy Department at Rizgary Teaching Hospital, Erbil, Kurdistan Region of Iraq. The study sample consisted of 60 individuals with chronic hemiparetic stroke. Participants received one session of weight-bearing ankle Mulligan Mobilisation with Movement. Ankle joint position sense (absolute error), non-weight-bearing dorsiflexion range of motion, weight-bearing dorsiflexion using the Weight-Bearing Lunge Test, balance using the Berg Balance Scale, and functional mobility using the Timed Up and Go test were assessed before and 5 minutes after the intervention. Normality of change scores was assessed using the Shapiro–Wilk test. Paired t-tests were used for normally distributed change scores, and Wilcoxon signed-rank tests were used for non-normally distributed change scores, with statistical significance set at $p < 0.05$.

Result: There was a significant improvement in ankle joint position sense (mean difference = −0.2698°), non-weight-bearing dorsiflexion (0.45°), and weight-bearing dorsiflexion (0.57°). There were no significant differences in balance or functional mobility.

Conclusion: Ankle proprioception and dorsiflexion range of motion were immediately enhanced after one ankle Mulligan Mobilisation with Movement session while balance and functional mobility was not. Further randomized controlled trials are needed to determine its long-term clinical effectiveness.

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Introduction

Stroke is one of the leading causes of early death and chronic disability worldwide and has a high impact on both the person who has had a stroke and health-care and social systems (Feigin et al., 2025). Despite advances in the treatment of acute stroke, many survivors could also have long-term, persistent neurological deficits that require long-term rehabilitation (Pollock et al., 2025). Common sequelae of chronic hemiparetic stroke are muscle weakness, spasticity, proprioception loss, poor joint mobility, and decreased postural control responsible for balance, gait and activities of daily living (ADL) impairments (Feigin et al., 2023).

Therefore, it is clinically important to develop effective rehabilitation strategies for the persistent impairments.

It is the ankle which is so significant for postural stability, body alignment and efficient gait. Good ankle dorsiflexion ROM and proprioception are key to a normal weight-bearing, postural control and dynamic balance of standing and walking (Ravichandran & Janakiraman, 2021). Other sensorimotor impairments following stroke include reduced dorsiflexion and impaired ankle joint position sense, both of which correlate with gait asymmetry and balance impairment and decreased functional ability (Alamer et al., 2021; Mao et al., 2022). Furthermore, impaired ankle proprioception has been shown to be strongly associated with impaired balance and gait performance, and hence the ankle is an important target for rehabilitation (Mao et al., 2022; Kochman et al., 2025).

Traditional stroke rehab exercises focus on building up muscle strength, retraining the body to move, stretching and orthotic management to help balance and increase independence (Winstein et al., 2016). Although these interventions are useful, a large proportion of chronic hemiparetic stroke patients still suffer from impairments of ankle proprioception, ROM and dorsiflexion sensorimotor control (Kochman et al., 2025). Therefore, more interest in rehabilitation strategies focusing on ankle sensorimotor function and talocrural joint mechanics for enhancing postural stability, gait function, and functional recovery is gaining momentum (Ravichandran & Janakiraman, 2021; Alamer et al., 2021).

Mulligan Mobilization with Movement (MWM) is a manual therapy technique that consists of a sustained accessory joint glide and active physiological movement to restore normal joint mechanics and optimize function (Mulligan, 2010). MWM is an active glide of the talus in the posterior direction with dorsiflexion in the weight bearing position. It is suggested that the mechanisms involve correction of the positional fault, restoration of the normal talocrural Arthrokinematics, increased per articular mechanoreceptor stimulation and improved sensorimotor integration, which may improve ankle proprioception and dorsiflexion range of motion (Vicenzino et al., 2011a, 2011b).Ankle Mulligan Mobilization with Movement has been shown to improve dorsiflexion range of motion, balance, and gait performance in individuals with chronic stroke when used as part of a rehabilitation program (Ravichandran & Janakiraman, 2021; Alamer et al., 2021; Nascimento et al., 2025; Büyükturan et al., 2022). Some research has demonstrated immediate outcomes of the ankle MWM in stroke rehabilitation, but evidence regarding the outcomes of ankle proprioception, dorsiflexion ROM, balance and functional mobility in chronic hemiparetic stroke (CHS) is limited (Nascimento et al., 2025; Büyükturan et al., 2022). These immediate responses could be a clue to the early biomechanical and sensorimotor effects of MWM, and

could contribute to the optimal application of MWM clinically. The purpose of this study was to explore the immediate effect of ankle Mulligan Mobilization with Movement on ankle proprioception, ankle dorsiflexion range of motion, balance and functional mobility of patients with chronic hemiparetic stroke.

METHODS

1-Study Design

A quasi-experimental, one group pretest–posttest study was to assess the immediate effect of a single session of ankle Mulligan Mobilization with Movement (MWM) on ankle proprioception, dorsiflexion range of motion (ROM), balance and functional mobility in chronic hemiparetic stroke. Each participant acted as their own control with outcome measures being taken immediately prior and 5 minutes following the intervention. All assessments were conducted by the same investigator in a standard order, minimizing variability in measurement techniques. The study was reported using the guidelines of the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement (Des Jarlais et al., 2004)

2- Study setting and participants

The study took place in the Physiotherapy Department at Rizgary Teaching Hospital, Erbil, Kurdistan Region of Iraq, from 10 February to 29 July 2026. Participants were patients on their regular visits to the Physiotherapy Department who suffered from chronic hemiparetic stroke. They were included in this study using consecutive sampling. Patients were screened for required in/exclusion criteria and asked consecutively to participate in the study until the required number was reached.

3-Sample Size

G*Power version 3.1.9.7 was used to calculate the sample size. A two-tailed paired-samples t-test was conducted using a priori power analysis with an assumed effect size (Cohen's d) of 0.40, a significance level (α) of 0.05 and a statistical power of 80%. From this, the minimum sample size was 52 participants. Research was conducted with 60 participants, to account for possible attrition and missing data.

4. Study Selection Criteria:

Inclusion Criteria:

1. Participants must have a stroke diagnosed by a neurologist, confirmed by computed tomography (CT) or magnetic resonance imaging (MRI) and have had a stroke onset ≥ 6 months prior to enrolment (Wechsler et al., 2018; Richards et al., 2026)
2. impaired ankle proprioception (joint position sense (JPS) absolute error > 5° on the paretic side (Ravichandran & Janaki Raman., 2021)
3. active ankle dorsiflexion range of motion < 15° (Ravichandran & Janaki Raman, 2021)
4. muscle strength of ankle dorsiflexors and plantar flexor ≥ 3 on Medical Research Council (MRC) (Kim & Eng., 2003)
5. Berg Balance Scale (BBS) score 35–50 (Veldema et al., 2020)
6. Timed Up and Go (TUG) test time > 12 s and able to stand independently for at least 30 s (Matsumoto et al., 2024)
7. body mass index (BMI) 18.5–35 kg/m2.
8. mild-to-moderate plantar flexor spasticity Modified Ashworth Scale (score 0–2).
9. cognitive function good enough to understand and follow simple verbal instructions.

Exclusion Criteria:

1. Participants were excluded if they had recurrent or bilateral stroke or other neurological condition that

affected function of the lower limb, balance or gait (e.g. Parkinson's disease, multiple sclerosis, peripheral neuropathy, traumatic brain injury or cerebellar disorders (Richards et al., 2026)
2. were cognitively or communicatively impaired (Winstein et al., 2016).
3. had severe ankle or foot osteoarthritis or had a lower limb fracture in the previous 6 months (Kim & Eng, 2003; Winstein et al., 2016).
4. had a fixed contracture or severe lower limb deformity, had lower limb orthopedic surgery in the previous 6 months (Kim & Eng., 2003; Winstein et al., 2016).
5. had severe ankle pain or acute inflammation or joint instability or infection or any contraindications to manual joint mobilisation (Billinger et al., 2014).
6. we're wearing a rigid lower limb orthosis during evaluation; were unable to stand independently for at least 30 s (Matsumoto et al., 2024).
7. had unstable cardiovascular, respiratory or other systemic disease that would preclude active physiotherapy (Norkin & White., 2025)
8. had severe plantar flexor spasticity (MAS score ≥3).

Outcome Measures

The same examiner in a standardized setting measured all outcome measures pre and post intervention. These assessments were conducted in the following order: ankle joint position sense (JPS), non-weight bearing ankle dorsiflexion range of motion (ROM), weight bearing ankle dorsiflexion ROM, Berg balance scale (BBS) and timed up and go (TUG) test:

1- Ankle Joint Position Sense

Proprioception of the ankle was tested by means of the active joint position sense (JPS) test with a standard transparent universal goniometer. The participants were seated in a long sitting position with the hip flexed at ~90° and the knee flexed at 25-30° to reduce gastrocnemius tension. An eye mask was used to prevent vision during the assessment. The examiner passively manipulated the affected ankle from a neutral position to a target angle of 10° dorsiflexion and held that angle for 5 seconds for proprioceptive encoding prior to returning to a neutral ankle position. Then the participants actively reproduced the target position, and the reproduced angle was recorded. Three trials were conducted, and the mean absolute error (AE) was defined as the absolute value of the difference between the target and reproduced angle and used for statistical analysis (Ravichandran & Janakiraman., 2021)

2- Non-Weight Bearing Ankle Dorsiflexion Range of Motion

The range of ankle dorsiflexion was measured with a standard transparent universal goniometer in a non-weight bearing position. The participants were seated comfortably with the involved lower limb supported, in order to reduce gastrocnemius tension. The fulcrum of the goniometer was positioned over the lateral malleolus of the fibula, the stationary arm was positioned along the long axis of the fibula and moving arm was parallel to the fifth metatarsal. Active dorsiflexion of the affected ankle was instructed to be performed within the participants' pain-free ROM of the ankle, avoiding any compensatory motion at the subtalar joint. Two measurements were obtained and the average was used for statistical analysis (Norkin & White, 2025).

3-Ankle Dorsiflexion Range of Motion (Weight-Bearing)

Weight Bearing Lunge Test (WBLT) was used to assess weight bearing ankle

dorsiflexion ROM. The participants were facing a wall with the affected foot in front of it, perpendicular to the wall and the heel could not be lifted off the ground during the evaluation. They were asked to do a forward lunge towards the wall, bringing the knee down until it reached the furthest position in dorsiflexion without raising the heel from the ground without feeling any pain. Inclinometer was positioned on top of the anterior surface of the tibia to obtain the tibialis inclination angle at the end of the movement. Two trials were conducted and the mean of the two was used in the statistical analysis (Powden et al., 2015).

4-Berg Balance Scale

Balance was evaluated by the Berg Balance Scale (BBS), an objective measurement of clinical balance that includes 14 functional balance items. There was an ordinal scale with 5 points (0–4) for each item and 56 maximum points for balance performance; the higher the score, the better the balance. Each task was administered following a standard procedure; a total score was recorded for statistical analysis (Kudlac et al., 2019)

5- Timed Up and Go Test

Timed Up and Go (TUG) test was used to evaluate functional mobility. The subjects were asked to get up from a regular armchair, walk 3 m forwards at their comfortable and safe speed, turn around, walk back to the armchair and sit on it down. A digital stopwatch was used to record the time in seconds to finish the test. Two trials were conducted and the shorter time was used for statistical analysis (Kear et al., 2023)

Intervention

All participants received Mulligan Mobilization with Movement (MWM), administered by the investigator who was trained in the Mulligan Concept. A single treatment session was applied to the affected ankle. The intervention was performed in a weight-bearing position with the participant standing and facing a wall. A Mulligan mobilization belt was positioned around the affected ankle, while the investigator was positioned behind and lateral to the affected limb. The investigator used both hands to stabilize and guide the ankle while a sustained posterior talar glide was maintained with the assistance of the belt. During the sustained glide, participants were instructed to perform active dorsiflexion by lunging the knee forward over the toes while maintaining the heel in contact with the ground. The mobilization was performed throughout a pain-free range. The intervention consisted of three sets of 10 repetitions, with a 1-minute rest period between sets (Alamer et al., 2021; Büyükturan et al., 2022)

Statistical Analysis

The data were analyzed using Graph Pad Prism version 9.0 (Graph Pad Software, San Diego, CA, USA). The continuous data were expressed as mean ± standard deviation (SD) and categorical data as numbers and percentages. The Shapiro–Wilk test was used to determine the normality of the change scores. Paired t-tests were used with normally distributed change scores and Wilcoxon signed-rank tests were used with non-normally distributed change scores. Cohen's d was calculated as the effect size for paired t-tests, and effect size (r) was calculated for Wilcoxon signed-rank tests. A p value < 0.05 was considered to be statistically significant.

Ethical Considerations

The study we did got approved by the Scientific ethics committee of Erbil Polytechnic University, Erbil, Iraq. They provided us with the number of approval 26/0113 HRE. We got it on 31 May 2026. Prior to the participation of each individual, we ensured that written consent is obtained. As per the rules of the Declaration of Helsinki, we did everything according to the rules. We used unique

codes for everyone, and removed any personal information from the information we kept about them in our studies. There was no force or compulsion involved, people had the opportunity to participate but if they did not they did not. They were free to leave the study at any time if they wished and this would not impact their care from their doctors. The study and the Ethical Considerations of the study were very important, to us. Ethical consideration of the study had been thought out appropriately.

RESULTS

The findings of the study are presented below: Participant characteristics, Descriptive statistics, Normality testing and Pre and Post comparison of outcome measures**.**

Participant Characteristics

There were no loss of follow-up or dropouts from the study, and a total of 60 participants with chronic hemiparetic stroke completed the study. The mean age was 60.38 ± 8.26 years (range, 45–74 years), the mean body mass index (BMI) was 26.39 ± 2.42 kg/m² (range, 19.9–32.6 kg/m²), and the mean time since stroke onset was 14.68 ± 5.88 months (range, 6–28 months).

Of the participants, 34 (56.7%) were male and 26 (43.3%) were female. Ischemic stroke (53, 88.3%) was the most common type of stroke, while the remaining 7 (11.7%) had a hemorrhagic stroke. Thirty-one (51.7%) participants had right-sided hemiparesis and 29 (48.3%) had left-sided hemiparesis. For assistive devices, 33 (55.0%) used a cane**,** 17 (28.3%) a walker, and 10 (16.7%) walked without an assistive device. Table 1 shows that the participants were demographically and clinically characterized in detail

Descriptive Statistics of Outcome Measures

Table 2 presents the descriptive statistics of all outcome measures before and after the intervention. The mean ankle joint position sense absolute error (JPS AE) decreased from 6.407 ± 0.6403 at baseline to 6.138 ± 0.7990 after the intervention. The mean non-weight-bearing ankle dorsiflexion range of motion (NWB DF) increased from 9.324° ± 1.766° to 9.772° ± 2.153°, while the mean weight-bearing ankle dorsiflexion range of motion (WB Lunge Test) increased from 27.74 ± 3.60° to 28.30 ± 3.772°. The mean Berg Balance Scale (BBS) score remained essentially unchanged (41.23 ± 2.28 vs. 41.23 ± 2.31). The mean Timed Up and Go (TUG) time changed slightly from 15.97 ± 1.53 s to 16.09 ± 1.82 s.

Normality Testing

Normality of the change scores (Δ = post − pre) was tested using the Shapiro–Wilk test Table 3. Ankle joint position sense (JPS AE), non-weight-bearing ankle dorsiflexion range of motion (NWB DF), and weight-bearing ankle dorsiflexion range of motion (WB Lunge Test) had normal distributions of change scores. Thus, the paired t-test was used for the analysis of these results. In contrast, the change scores for the Berg Balance Scale (BBS) ($W = 0.750$, $P < 0.001$) and Timed Up and Go (TUG) test ($W = 0.799$, $P < 0.001$) were not normally distributed. Hence Wilcoxon signed-rank test was employed for these outcome.

Immediate effects of Mulligan Mobilisation with Movement

Table 4 compares all outcome measures before and after treatment and figures 1 and 2 show the changes over time relative to baseline. There were significant improvements in JPS AE ($df=59$, two-tailed $t=4.113$, $P =0.0001$). Mean difference post minus pre was -0.2698 degree (95% CI, -0.4011 to -0.1386) that means JPS error was reduced, with a

moderate effect size (0.53). There were significant improvements in NWB DF as compared prior to treatment (t=3.299, P=0.0016). Mean difference was 0.45 degree (95% CI, 0.18-0.72) which shows that NWB DF improved. There was a small-moderate effect size observed, (0.43). In term of WB Lunge Test (WB DF), there was a significant improvement after the treatment (t=2.847, P=0.0061). Mean difference= (0.57 degree ((95% CI, 0.17 to 0.96) and therefore with small effect size (0.37). In terms of functional balance and functional mobility, no statistically significant improvements were found in the study participants after one session. No significant difference was in Berg balance scale pre- and post as detected via the Wilcoxon signed-rank test (W=0.000, P>0.9999). It could not detect the effect=0.00. Similarly, for Timed up and Go (TUG), no significant difference was in between the pre-and post-scores of the patients (W=133.0, P=.3240). There is only small effect so far detected in this field (0.11).

Key Findings

The results of the present study can be briefed as follows:

1-A single session of ankle Mulligan Mobilization with Movement led to an immediate improvement in ankle proprioception, as evidenced by decreased JPS AE.

2-There was a significant immediate improvement in ankle dorsiflexion ROM in both the non-weight-bearing and weight-bearing tests.

3-No improvement was observed in balance immediately, using the Berg Balance Scale.

4-There was no immediate significant change in functional mobility (Timed Up and Go test).

5-The results indicated that the immediate effects were more evident in ankle-related outcomes than in functional outcomes.

Table 1. Demographic and clinical characteristics of study participants (N = 60)

Variable	Value
Continuous variables, mean ± SD (range)	
Age (years)	60.38 ± 8.26 (45–74)
BMI (kg/m²)	26.39 ± 2.42 (19.9–32.6)
Time since stroke (months)	14.68 ± 5.88 (6–28)
Categorical variables, n (%)	
Sex	
Male	34 (56.7%)
Female	26 (43.3%)

Stroke type	
Ischemic	53 (88.3%)
Hemorrhagic	7 (11.7%)
Affected side	
Right	31 (51.7%)
Left	29 (48.3%)
Assistive device	
Cane	33 (55.0%)
Walker	17 (28.3%)
None	10 (16.7%)

Note. Continuous variables are presented as mean ± standard deviation (SD) with range (minimum–maximum). Categorical variables are presented as frequency (n) with percentage (%). N = 60. BMI = body mass index.

Table 2. Descriptive statistics of outcome measures pre- and post-intervention (N = 60)

Outcome	Assessment	Mean ± SD	Median (IQR)	Min–Max
JPS AE (°)	Pre	6.407 ± 0.6403	6.450(5.930–6.758)	5.040–8.070
	Post	6.138 ± 0.7990	6.085(5.650–6.655)	4.580–8.140
NWB DF (°)	Pre	9.324 ± 1.766	9.130(8.100–10.71)	5.460–13.25
	Post	9.772 ± 2.153	9.735(8.420–10.86)	5.720–14.88
WB DF (°)	Pre	27.74 ± 3.601	27.95(24.68–31.03)	21.06–33.86
	Post	28.30 ± 3.772	28.23(25.31–30.84)	20.77–34.45
BBS (points)	Pre	41.23 ± 2.280	41.00 (39.00–43.00)	38.00–46.00
	Post	41.23 ± 2.310	41.00 (39.00–43.00)	37.00–46.00
TUG (s)	Pre	15.97 ± 1.528	16.00 (14.64–17.24)	13.07–18.82
	Post	16.09 ± 1.820	16.20 (15.18–17.44)	12.13–19.82

Note. Data are presented as mean ± standard deviation (SD) and median with interquartile range [IQR] for all variables. Range = minimum to maximum. JPS AE = joint position sense absolute error; NWB DF = non-weight-bearing dorsiflexion; WB Lunge = weight-bearing dorsiflexion; BBS = Berg Balance Scale; TUG = Timed Up and Go.

Table 3. Shapiro-Wilk test of normality for change scores (N = 60)

Variable	W-statistic	p-value	Distribution	Test to Use
Δ JPS AE	0.9726	0.1958	Normal	Paired t-test
Δ NWB DF	0.967	0.101	Normal	Paired t-test

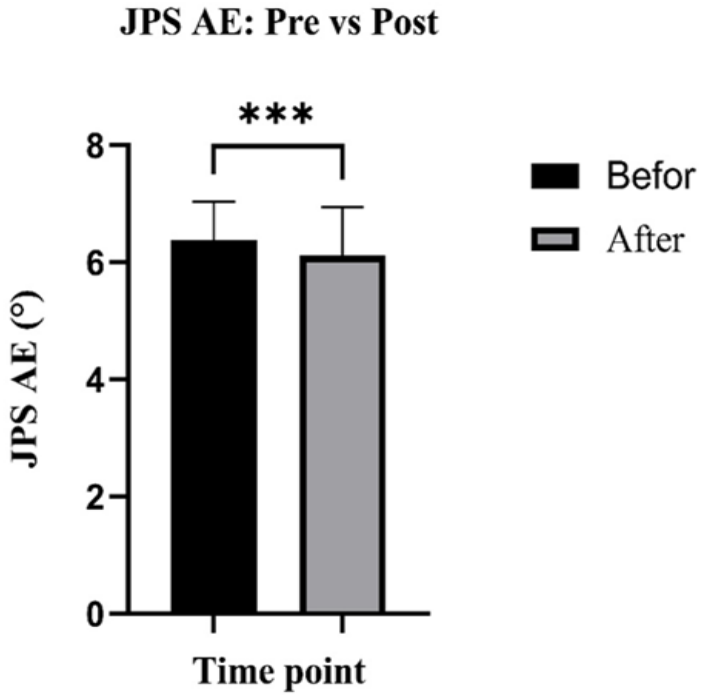
Δ WB Lunge	0.977	0.328	Normal	Paired t-test
Δ BBS	0.750	<0.001	Non-normal	Wilcoxon signed-rank
Δ TUG	0.799	<0.001	Non-normal	Wilcoxon signed-rank

Note. Δ = Post − Pre for all outcomes. Normality was assessed using the Shapiro-Wilk test. A p-value > 0.05 indicates that the change scores are normally distributed. A p-value < 0.05 indicates non-normal distribution. JPS AE = joint position sense absolute error; NWB DF = non-weight-bearing dorsiflexion; WB Lunge = weight-bearing dorsiflexion; BBS = Berg Balance Scale; TUG = Timed Up and Go.

Table 4. Comparison of pre- and post-intervention outcome measures (n = 60)

Outcome	**Pre**	**Post**	**Mean/Median Difference (95% CI)**	**(*P* value)**	**Test statistic,df**	**Effect size**
JPS AE (°)	6.407± 0.6403	6.138± 0.7990	−0.2698(−0.4011 to −0.1386)	0.0001	*t*(59)= 4.113	*d* = 0.53
NWB DF (°)	9.32 ± 1.77	9.77 ± 2.15	0.45(0.18–0.72)	0.0016	*t*(59)= 3.299	*d* = 0.43
WB Lunge (°)	27.74 ± 3.60	28.30 ± 3.77	0.57(0.17 – 0.96)	0.0061	*t*(59)= 2.847	*d* = 0.37
BBS (points)	41.00(39.00–43.00)	41.00(39 – 43.00)	0.00(0.00 – 0.00)	>0.9999	*W* = 0.000	*r* = 0.00
TUG (s)	16 (14.64 – 17.24)	16.20(15.18–17.44)	0.00 (−0.10 to 0.20)	0.3240	*W* = 133.0	*r* = 0.11

Note. Data have been presented as mean ± SD or median (IQR). Joint position sense absolute error (JPS AE), non-weight bearing dorsiflexion (NWB DF), weight-bearing dorsiflexion (WB Lunge), Berg Balance Scale (BBS), Timed Up and Go (TUG).



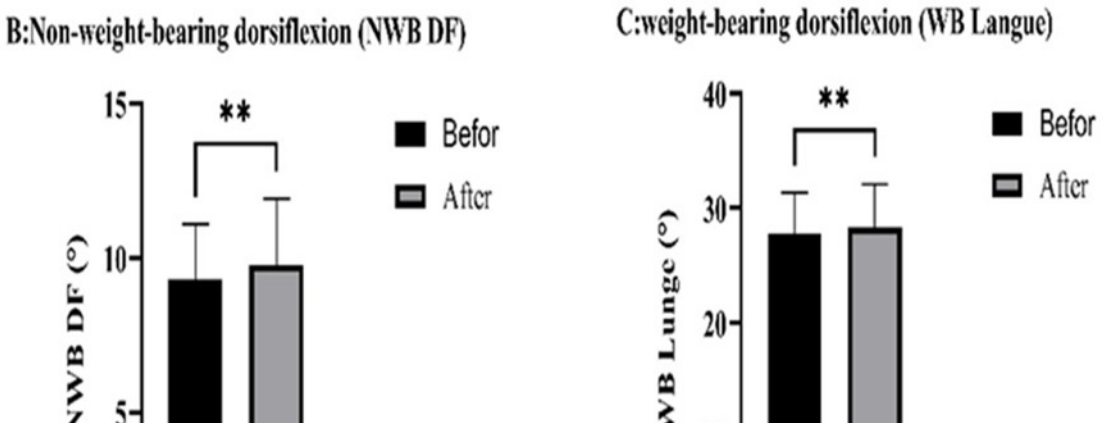


Figure 1. Changes in ankle-related outcomes before and after the intervention: (A) ankle joint position sense absolute error



Figure 1. Changes in ankle-related outcomes before and after the intervention: ankle dorsiflexion range of motion under(B) non-weight bearing dorsiflexion and (C) weight –bearing dorsiflexion

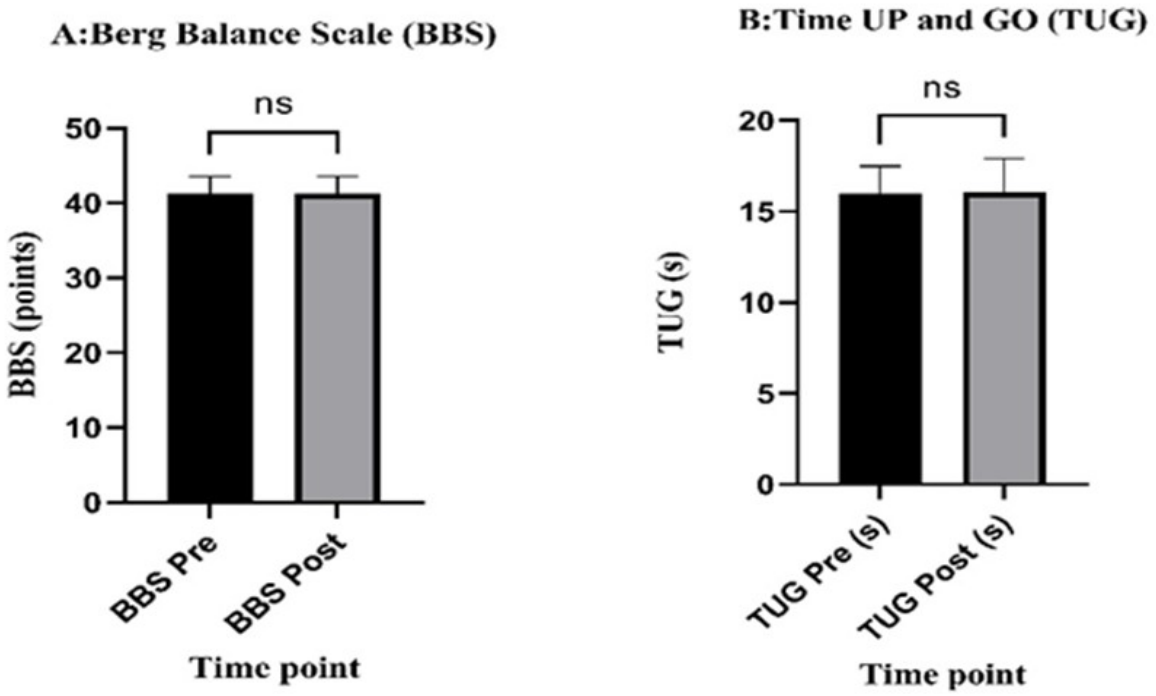


Figure 2 Shows the balance outcomes before and after the intervention, demonstrating the following: (A) Berg Balance Scale and (B) Timed Up and Go.

DISCUSSION

The immediate influence of a single session of MWM on the ankle proprioception, dorsiflexion range of motion (ROM), balance and functional mobility of chronic hemiparetic stroke patients was studied. Results showed that there were significant immediate improvements in ankle joint position sense, non-weight bearing ankle ROM and weight bearing ankle ROM. But there was no significant immediate improvement in functional balance and functional mobility. Together, these findings suggest that ankle MWM may immediately improve ankle proprioception and

dorsiflexion ROM and that repeated MWM sessions may be necessary along with a comprehensive rehabilitation program for functional recovery (Ravichandran & Janakiraman, 2021; Matsumoto et al., 2024)

The present study indicated that ankle MWM resulted in immediate enhancement of ankle joint position sense. The change in JPS absolute error (AE) was small and effect size was moderate, suggestive of moderate amount of improvement after intervention. The results agree with previous studies that have shown improvements in lower limb function after ankle mobilisation in people with stroke (Ravichandran & Janakiraman, 2021; Matsumoto et al., 2024) Also, the role of ankle proprioception in balance and gait function post stroke has been extensively studied (Winstein et al., 2016 , Billinger et al., 2014)The observed improvement may be explained by the proposed biomechanical and neurophysiological mechanisms of MWM, where improved joint mechanics, and thus an increased afferent input from periarticular mechanoreceptors, leads to improved proprioceptive feedback(Kim & Eng, 2003; Ravichandran & Janakiraman, 2021)

Although ankle proprioception may play a role in improving functional outcome (Cho & Kim, 2021,;Matsumoto et al., 2024;Billinger et al., 2014) there is a greater likelihood that this will happen with repeated sessions during rehabilitation rather than after a single treatment. While the difference was significant, the amount of change was minimal, and should be interpreted with caution as no MCID (Minimal clinically important difference) has been established for ankle joint position sense in chronic stroke individuals.

This current study also showed immediate small improvement in weight-bearing and non-weight-bearing ankle dorsiflexion ROM after the intervention. The results corroborate with previous studies, showing that MWM led to greater dorsiflexion at the ankles after MWM in chronic stroke patients (Ravichandran & Janakiraman, 2021; Matsumoto et al., 2024). A systematic review also led to a conclusion that ankle mobilizations techniques are effective in enhancing ankle mobility and functional outcomes following stroke (Ravichandran & Janakiraman, 2021). Immediate results may be related to the continuous posterior glide that occurred by active dorsiflexion, which may help to re-establish normal talocrural joint mechanics (Ravichandran & Janakiraman, 2021; Kim & Eng, 2003). Good ankle dorsiflexion is required for the normal gait progression of the tibia as well as for functional activities like walking on stairs and sit to stand. Thus, small gains in dorsiflexion ROM may provide a basis for functional rehabilitation when paired with task specific training (Cho & Kim, 2021; Matsumoto et al., 2024). However, the amount of enhancement was modest, perhaps because the assessment took place immediately after the MWM treatment while other studies used multiple MWM treatments over a period of weeks (Kim & Eng, 2003; Matsumoto et al., 2024)

Improvements in dorsiflexion ROM and ankle proprioception were observed but no immediate changes were seen in Berg Balance Scale (BBS) or Timed Up and Go (TUG) test. In previous studies, similar results were seen when the MWM was repeated over a period of time and conventional rehabilitation was also included (Ravichandran & Janakiraman, 2021; Matsumoto et al., 2024), and only after repeated MWM sessions significant improvements in balance and mobility were seen. Balance and mobility is dependent on many factors such as proprioception, muscle strength, postural control, coordination and motor planning (Billinger et al., 2014; Winstein et al., 2016). Further, improvements in functional balance and mobility were not immediately observed in this study, even though ankle complications decreased, perhaps due to lower limb muscle weakness, poor trunk control, spasticity, and diminished motor coordination frequently found after stroke (Billinger et al., 2014: Matsumoto et al., 2024). Thus, enhancing ankle performance may not be enough to elicit any significant improvements in functional performance at a higher level after a single treatment. In addition, both BBS and TUG may not have been sufficiently sensitive to detect subtle immediate changes following a single session.

Immediate improvement in ankle proprioception and in dorsiflexion ROM indicates that ankle MWM may be considered as a potential adjunct to conventional stroke rehabilitation before task-specific training (Ravichandran & Janakiraman, 2021; Matsumoto et al., 2024). However, as no immediate improvement was seen in functional balance or mobility, ankle MWM should be part of a more extensive rehabilitation regime that features strengthening exercises, balance training, gait re-education and functional, task specific practice.

This study specifically examined the immediate effects of a single ankle MWM session on ankle proprioception, dorsiflexion ROM, balance and functional mobility in patients with chronic hemiparetic stroke. The intervention was the same standardised intervention for all participants taught by the same physiotherapist and all assessments were conducted under the same conditions before and after the intervention, minimising procedural variability. However, being a one-group pretest–posttest design without a control group, it is not possible to conclude that the intervention caused the observed results. Additionally, the results presented only the immediate effects of one treatment session and may not be applicable to the other stroke populations. The BBS and TUG are good and commonly used clinical outcome measures but may not be sensitive enough to pick up small changes immediately after one treatment session.

CONCLUSION

Immediate changes following one session of ankle Mulligan Mobilization with Movement (MWM) included statistically significant improvements in ankle joint position sense and ankle dorsiflexion range of motion in both the non-weight-bearing and weight-bearing states in chronic hemiparetic stroke patients. There was no immediate statistically significant improvement, however, in functional balance or functional mobility.

The results of this study indicate that ankle MWM may be a beneficial adjunct intervention to enhance ankle proprioception and mobility in stroke rehabilitation.

RECOMMENDATIONS AND FUTURE DIRECTIONS

Future randomized controlled trials with appropriate control or sham intervention groups are needed to confirm the present findings. Further research into more than one treatment session, longer follow-up, and more participants should be explored. Objective outcome measures including instrumented gait analysis, postural stability assessment and ankle muscle strength might give a fuller picture of the effects of ankle MWM. The optimal dosage for treatment, and whether the effect on treatment varies with the severity, chronicity and baseline functional status of the stroke, are also subjects for future study.

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Declarations

Author contributions

The author was involved in conceptualization, methodology, investigation, data curation, formal analysis and preparation, review and editing of the manuscript.

Competing interests

The authors have no conflicts of interest related and/or attributable to this work.

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Availability of data and materials.
All data reported in this study are available from the corresponding author upon reasonable request.

AI policy statement
Artificial intelligence (AI)-assisted tools were used only for purposes of aiding literature searching and assisting language polishing during the preparation of the manuscript. Potentially relevant literature was found using Perplexity as a supporting medium and QuillBot and Hue Write were used to amend language use, including amelioration of grammar, clarity and style. All of the suggestions made by these respective tools were reviewed and revised thoroughly by the authors. No form of AI was used in study design, data collection, statistical analysis, interpretation of the results or formation of figures. The authors assert their responsibility over the manuscript.

Ethical Approval

Eethical approval was given under Approval No. 26/0113 HRE on 31 May 2026 by Scientific Ethics Committee of Erbil Polytechnic University,

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