

Effects of 3D Shoulder Mobilization Compared to Passive-Active Exercises on Pain and Arm Function in Post-Stroke Hemiplegic Shoulder Pain

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Submitted : 2026-07-09; Accepted : 2026-08-18; Published : 2026-10-01

ABSTRACT

Introduction: Hemiplegic Shoulder Pain (HSP) is a common musculoskeletal complication in post-stroke patients and significantly restricts rehabilitation and functional independence. 3D shoulder mobilization is an intervention currently being developed to address pain and improve arm function compared to conventional passive-active shoulder exercises. Both interventions have been widely used clinically, but no studies have compared their effectiveness. To investigate the effects of 3D shoulder mobilization and passive-active shoulder exercises on pain relief and arm functional ability in post-stroke patients. **Methods:** This study used an experimental design. A purposive random sampling technique was used to select participants, with the sample size determined based on previous literature. Participants were randomly allocated into two groups. Interventions were administered six times over a 3-week period. Functional ability and pain intensity were measured using the Visual Analog Scale (VAS) and Shoulder Pain and Disability Index (SPADI) questionnaires before (pretest) and after (post-test) the intervention. Within-group differences (pretest vs. post-test) were analyzed using the Wilcoxon signed-rank test, while between-group differences were analyzed using the Mann-Whitney U test. **Results:** The statistical test results for each group showed a significant decrease in pain intensity and an increase in functional ability. Result for the Intervention Group are VAS $p=0.001$; SPADI pain scale $p=0.001$; and SPADI disability scale $p=0.007$ and for the Control Group are VAS $p=0.001$; SPADI pain scale $p=0.001$; and SPADI disability scale $p=0.011$. Comparison of the two groups showed equivalent results in both post-intervention groups, with no statistically significant differences in results between the Intervention Group and the Control Group (VAS $p=0.063$; SPADI pain scale $p=0.134$; and SPADI disability scale $p=0.340$). **Conclusion:** 3D shoulder mobilization and passive-active shoulder exercises are both effective in reducing post-stroke HSP in the short term. However, a 3-week (6-session) intervention is not sufficient to provide significant functional improvements in the arm.

Keywords: Post-Stroke, Hemiplegic Shoulder Pain, 3D Shoulder Mobilization Passive-Active Exercise, VAS, SPADI.

ISSN 2722 – 9610
E –ISSN 2722 - 9629

INTRODUCTION

Optimal shoulder function is a prerequisite for effective hand function, as well as for performing various mobilization, ambulation, and activities of daily living (ADL). Hemiplegic Shoulder Pain (HSP) is a common complication in stroke patients with an incidence rate of between 48-84% (Wiener J, et al., 2018). Research conducted by Adey-Wakeling et al found that 29% of HSP occurred up to 12 months after stroke, with the highest level of pain

occurring in the fourth month (Karaahmet OZ, et al., 2014). In addition, research in 2023 at the Mahar Mardjono National Brain Center Hospital showed that 77% of stroke patients experienced HSP within the first year after stroke (Dewi Suci, 2024).

Stroke will change the alignment of clavicle, scapula, and humerus in the three-dimensional plane, potentially causing sub acromial pain syndromes, rotator cuff disorder, biceps tendonopathy, bursitis, shoulder



impingement, and ligament tears (Kalichman L, et al, 2011). Alignment changes can also cause changes in muscle tone, muscle strength, abnormal synergistic movement patterns, and changes in the tensile strength of two opposing muscle groups (Kalichman L & Ratmanský M, 2011). Reduced mobility of the hemiparetic arm can also cause soft tissue stiffness, resulting in changes in joint alignment during active and passive movements, and causing HSP.

Shoulder pain is generally a disorder of the musculoskeletal system. Shoulder pain is usually caused by frozen shoulder, which occurs due to trauma or degenerative changes. Several guidelines on interventions for shoulder pain due to musculoskeletal conditions recommend passive and active ROM exercises, positioning techniques to optimize joint alignment, and patient education (Hebert D, et al., 2015). These guidelines also recommend joint mobilization. The joint mobilization techniques are upward rotation of scapula and external rotation of humerus with the hemiplegic arm passively elevated to 90°. This techniques are believed to reduce the occurrence of sub acromial pain syndromes (Ludewig PM, et al, 2011). This mobilization technique is unidimensional and occurs in one plane of motion. Previous research identified that clavicle, scapula, and humerus rotate three-dimensional in the sagittal, coronal, and transverse planes (De Baets L, et al., 2016). Based on this research, the unidimensional mobilization theory was developed into three-dimensional mobilization to address shoulder pain in post-stroke patients.

In the neurology literature, various studies have examined the relationship between changes in the rotational movement patterns of the clavicle, scapula, and humerus and the occurrence of HSP. One study of HSP reported that maintaining glenohumeral joint alignment requires stabilization of the humeral head, specifically during elevation, lateral rotation of scapula, and external rotation of humerus (Ratanapinunchai et al., 2019). The study stated that "loss of scapulo humeral rhythm will result in a cycle of pain, inflammation, and the risk of damage to the rotator cuff due to ischemia or compression." Other studies have stated that

imbalances in the strength and coordination of the rotator cuff muscles in stroke patients result in impaired scapula humeral rhythm, and "HSP is associated with spastic muscle imbalance and limited ROM."

The cause of HSP is not a single structure, but rather a combination of shoulder subluxation, spasticity of the subscapularis and pectoralis major muscles, limited range of motion (ROM), altered scapular mechanics, and soft tissue injury due to improper mobilization exercises (Murie-Fernandez, M, et al., 2012). Therefore, they emphasize that joint mobilization should be performed carefully, within a safe range of motion, and avoid aggressive movements that can exacerbate pain and tissue damage. The review also suggests that a physiotherapy approach is the primary intervention compared to pharmacological therapy because it can correct the underlying mechanical causes of HSP.

Further expanded on this concept by explaining that the diagnosis and management of HSP must simultaneously consider the various biomechanical and neurological causes (Vasudevan & Browne 2014). Effective treatment requires a combination of pain control, restoration of joint mobility, increased scapular stability, normalization of muscle tone, and functional upper extremity exercises. They emphasized that manual intervention and therapeutic exercises are key components of rehabilitation because they can address mobility limitations while improving arm function. Based on these two reviews, 3D Shoulder Mobilization has a strong theoretical basis because this technique does not only provide passive movement in one plane of motion, but follows the three-dimensional physiological movement pattern of the scapulohumeral complex.

In contrast, passive-active exercises are standard therapy aimed at maintaining range of motion, preventing contractures, and increasing muscle activation through gradual active exercises. While effective in maintaining mobility, these exercises are generally more focused on increasing movement than on correcting specific joint biomechanics. Consequently, in patients with arthrokinematic disorders or scapulohumeral dysfunction,



passive-active exercises alone may not be sufficient to address the mechanical causes of HSP.

While both review articles conclude that physiotherapy is the primary intervention in the management of HSP, they also emphasize that scientific evidence regarding the most effective mobilization techniques is limited. Most available studies evaluate only conventional exercises, positioning, slings, electrical stimulation, or injections, while evidence regarding the effectiveness of more specific manual mobilizations on shoulder biomechanics is still inadequate. Furthermore, few studies have directly compared 3D Shoulder Mobilization with Passive-Active Exercises on clinical outcomes such as pain and arm function.

Therefore, the study "Effects of 3D Shoulder Mobilization Compared to Passive-Active Exercises on Pain and Arm Function in Post-Stroke Hemiplegic Shoulder Pain" is relevant because it aims to fill this evidence gap. This study is expected to provide information on whether a three-dimensional mobilization approach oriented towards shoulder biomechanical restoration provides greater benefits than conventional passive-active exercises in reducing pain and improving upper extremity function in post-stroke patients with Hemiplegic Shoulder Pain. The results of this study also have the potential to be the basis for the development of evidence-based physiotherapy protocols for the rehabilitation of stroke patients with complications of hemiplegic shoulder pain. This study has been approved by The National Brain Centre Research Ethics Committee according to certificate number DP.04.03/D.XXIII.9/139/2024 dated July 9th, 2024

METHODS

Based on previous research on the effectiveness of 3D mobilization by Pain, L.A.M, et al (2020) involving 26 people, the researchers determined a sample size for this study of 30 people. Thirty (30) patients were recruited based on predetermined inclusion and exclusion criteria. All patients are stroke patient in National Brain Center Hospital. The study was conducted from

August 2024 to February 2025. The inclusion criteria were (a) patients less than one year post-stroke, (b) all age groups, (c) male and female, (d) experiencing shoulder pain and limited arm function, and (e) willing to participate in the research program (signed informed consent). The exclusion criteria were (a) patients with cognitive impairment, (b) aphasia, and (c) patients with pre stroke shoulder pain.

Participants were allocated into two groups randomly using the simple randomization method through the technique of patients who met the criteria first entered the intervention group then the second patient to the control group and so on alternately. A total of 15 patients were assigned to the intervention group receiving 3D shoulder mobilization, and 15 patients were assigned to the control group receiving passive-active exercises. Both groups received 15–30 minutes of exercise. Before the intervention, both groups received sensorimotor stimulation and posture correction exercises.

The 3D shoulder mobilization intervention was performed with the patient sitting upright on a chair without armrests, with both feet flat on the floor to maintain trunk stability. The patient's paretic arm was positioned in a relaxed resting position, with 55° abduction and 30° horizontal adduction, fully supported by the physiotherapist's arm. The physiotherapist stood on the lateral side to provide fixation on the scapula and performed manual mobilization in the form of traction, gliding, and three-dimensional rotation of the humeral head (Figure 1). The exercises were given for 15–20 minutes.



Figure 1. 3D Shoulder Mobilization

Passive-active shoulder exercises begin with passive range of motion (PROM) movements guided entirely by the physiotherapist at the glenohumeral joint in flexion, extension, abduction, adduction, and rotation within the patient's pain tolerance to maintain connective tissue mobility. Next, the patient is instructed to perform active exercises (active-assisted or active exercise) independently or with minimal assistance from the therapist, moving the arm according to functional shoulder movement patterns to stimulate local blood circulation and motor activation. Three sets of 10–12 repetitions are performed in each direction of movement (Figure 2).

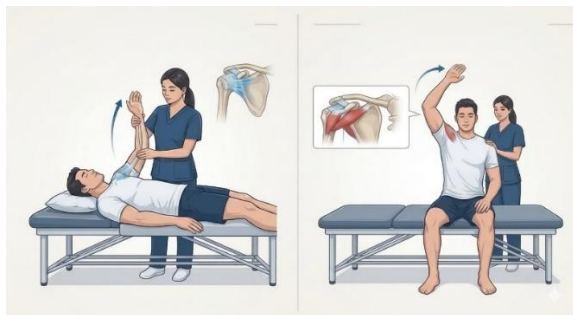


Figure 2. Passive-Active Shoulder Exercises

Arm functional ability was assessed using the SPADI instrument, which has a total score of 130. The SPADI is a valid and reliable functional questionnaire (Cronbach's alpha > 0.85) to measure the impact of shoulder disorders. This instrument is divided into two methodological subscales: a pain scale (5 items, total score 50) and a disability scale (8 items, total score 80). In addition to the SPADI, pain intensity was assessed using the VAS instrument, a 10 cm horizontal line (score 0–10) to measure the patient's pain intensity instantly and objectively during movement. Measurements for both instruments (SPADI and VAS) were carried out twice, namely before the first intervention (pre-

test) and after the sixth intervention ended (post-test).

For data analysis, the statistical tests used are: Wilcoxon Signed-Rank Test: Used to test paired differences (within-group) before and after the intervention in each group. Mann-Whitney U Test: Used to test independent differences (between-group) between the intervention group and the post-treatment control group

RESULTS

The study involved 30 stroke patients, with 15 receiving 3-D shoulder mobilization and 15 receiving shoulder range of motion exercises. There was no difference in age and gender distribution between the two groups (Table 1).

Table 1. Demographic characteristic of the patients

The characteristic	Intervention group (n=15)	Control group (n=15)	p-value
Age			
< 60 years	5 (33%)	9 (60%)	0.319
> 60 years	10 (67%)	6 (40%)	
Mean (minimum:medium)	60.53 (44:82)	55.73 (36:70)	
Sex			
Male	9 (60%)	10 (67%)	0.710
Female	6 (40%)	5 (33%)	
Type of stroke			
Stroke Ischemic	15 (100%)	15 (100%)	1.000
Stroke Hemorrhagic	0 (0%)	0 (0%)	

All patients in the study were ischemic stroke patients, with a preponderance of male patients compared to female patients. The age distribution in the control group was higher among patients under 60 years (60%), while in the intervention group, there were higher among patients over 60 years (67%). Both groups showed improvement in arm functional ability and pain before and after the intervention (Table 2).

Table 2. Level of pain and arm function after intervention in Post-Stroke Hemiplegic Shoulder
Pain

Interventions group				
Arm Functional Ability	Mean	SD	p-value	r
Pain (VAS)			0.001	0.88
Pre intervention	6.73	1.83		
Post intervention	3.00	1.36		
Pain (SPADI)			0.001	0.88
Pre intervention	67.20	23.38		
Post intervention	33.46	14.91		
Disability (SPADI)			0.007	0.69
Pre intervention	86.58	19.02		
Post intervention	78.50	26.35		
Control group				
Arm Functional Ability	Mean	SD	p-value	r
Pain (VAS)			0.001	0.89
Pre intervention	6.20	1.74		
Post intervention	3.53	1.64		
Pain (SPADI)			0.001	0.88
Pre intervention	59.07	14.01		
Post intervention	37.07	15.89		
Disability (SPADI)			0.011	0.66
Pre intervention	72.02	26.40		
Post intervention	64.65	28.07		

Based on the Wilcoxon signed-rank test results in the intervention group, there was a significant decrease in shoulder pain intensity after the intervention. Visual Analog Scale (VAS) scores decreased from a mean of 6.73 ± 1.83 before the intervention to 3.00 ± 1.36 after the intervention ($p = 0.001$), with a large effect size ($r = 0.88$). Similarly, pain scores based on the Shoulder Pain and Disability Index (SPADI) decreased significantly from 67.20 ± 23.38 to 33.46 ± 14.91 ($p = 0.001$), with a large effect size ($r = 0.88$). A significant change was also found in the SPADI disability component, from 86.58 ± 19.02 to 78.50 ± 26.35 ($p = 0.007$), with a large effect size ($r = 0.69$).

A significant reduction in pain scores was also found in the control group using the same

Wilcoxon signed-rank test. VAS scores decreased from 6.20 ± 1.74 to 3.53 ± 1.64 ($p = 0.001$), with a large effect size ($r = 0.89$). SPADI pain scores also decreased from 59.07 ± 14.01 to 37.07 ± 15.89 ($p = 0.001$), with a large effect size ($r = 0.88$). Furthermore, SPADI disability scores changed significantly from 72.02 ± 26.40 to 64.65 ± 28.07 ($p = 0.011$), with a large effect size ($r = 0.66$).

Overall, the Wilcoxon signed-rank test results showed that both the intervention and control groups experienced significant improvements in shoulder pain and arm function over the study period. All effect sizes were in the large category ($r = 0.66-0.89$), indicating that the changes were not only statistically significant, but also had strong clinical significance

Table 3. Differences in improvement in pain and disability scales between the intervention group and the control group

Arm Functional Ability	Mean	SD	p-value	r
Pain (VAS)	3.200	1.42	0.063	0.34
Pain (SPADI)	27.73	18.48	0.134	0.27
Disability (SPADI)	7.82	12.77	0.340	0.17

Based on the Mann-Whitney U test results, there was no significant difference in pain or disability scores between the intervention and control groups after the intervention. For the Visual Analog Scale (VAS) pain score, the mean decrease in the intervention group was 3.20 ± 1.42 , with the Mann-Whitney U test result of $p = 0.063$ test result and a medium effect size ($r = 0.34$). Although the intervention group showed a trend toward greater improvement, this difference did not reach statistical significance ($p > 0.05$).

For the Shoulder Pain and Disability Index (SPADI) pain score, the mean decrease was 27.73 ± 18.48 , with a Mann-Whitney test result of $p = 0.134$ and a small to medium effect size ($r = 0.27$). These results indicate no significant difference between the two groups in pain scores based on the SPADI. Similarly, for the SPADI disability variable, the Mann-Whitney U test revealed a mean decrease was 7.82 ± 12.77 , with a p-value of 0.340 and a small effect size ($r = 0.17$). These



results indicate that functional improvement as measured by the SPADI disability component did not differ significantly between the intervention and control groups.

Overall, the the Mann-Whitney U test results showed no significant difference in pain reduction or disability between the intervention and control groups (all p-values > 0.05). However, the effect sizes varied, ranging from moderate on the VAS ($r = 0.34$), small to moderate on the SPADI pain ($r = 0.27$), and small on the SPADI disability ($r = 0.17$). These findings suggest that the intervention did not provide statistically significant benefits over the control group on any of the measured parameters.

DISCUSSION

Demographic characteristics in both groups showed no significant differences (all $p > 0.05$), indicating comparable baseline characteristics. The mean age was 60.5 years in the intervention group and 55.7 years in the control group, while 67% of participants were male, and all patients were diagnosed with ischemic stroke. Since no statistically significant differences were found in baseline demographic variables, these characteristics were unlikely to influence the treatment outcomes. Therefore, subsequent between-group differences can be interpreted with greater confidence as being attributable to the intervention rather than demographic imbalance. This finding improves the study's internal validity and supports the reliability of the intervention's effectiveness.

The 3-D shoulder mobilization intervention uses a roll and glide technique based on biomechanical principles of the glenohumeral joint in three planes of motion simultaneously (sagittal, frontal, and transverse) (Pain, et al., 2020). This technique produces neurophysiological effects in the form of stimulation of type I and II mechanoreceptors in the joint capsule, which closes the pain gate (pain gate theory) and stretches the joint capsule (capsular pattern restriction) (Bialosky, J.E., et al., 2009). Furthermore, the traction and oscillation movements of 3-D mobilization stimulate synovial fluid production, which reduces friction and facilitates arm movement. By

reducing pain, range of motion and muscle strength increase, ultimately restoring arm function (Kisner, C., & Colby, L. A., 2012)

Passive-active shoulder exercises are beneficial for improving local blood circulation, triggering the release of endorphins, and metabolizing pain-inducing substances (bradykinin and prostaglandins). Furthermore, passive-active exercises can maintain muscle elasticity and prevent tissue adhesions (Joel D Trinity & Russle S Richardson, 2020).

Based on the results of statistical analysis, there was no significant difference between providing 3D shoulder mobilization and passive-active shoulder exercises in reducing shoulder pain ($p > 0.05$). This shows that both interventions have equivalent capacity in reducing pain intensity in patients within 3 week intervention period (Kachingwe et al., 2008). The reduction in pain in the Control Group was driven by improvements in local circulation and the release of endogenous endorphins due to active-passive movement (Junior, A. H., & Dewi, R. G. N. (2024). Meanwhile in the Intervention Group, pain reduction occurred through a nociceptive inhibition mechanism in the dorsal horn of the spinal cord due to stimulation of mechanoreceptors during 3D mobilization (Bialosky et al., 2009). In the short term (6 sessions), these two neurophysiological mechanisms provide comparable pain relief effects (Ho et al., 2009).

This equivalence in short-term pain mitigation is highly consistent with recent literature examining multi-planar manual therapy protocols. A recent clinical trial demonstrated that incorporating passive joint mobilization into standard neuromuscular exercises yields robust, comparable short-term relief on the Shoulder Pain and Disability Index (SPADI) pain subscale, validating the immediate neurophysiological pain-gate mechanism observed in our study (Yiasemides et al., 2024). Similarly, head-to-head evidence evaluated by primary studies on advanced joint glides confirms that manual touch combined with structured passive-active mobilization strategies shares a shared therapeutic pathway in modulating high tissue irritability during acute healing phases. Both



approaches successfully break down localized inflammatory cycles—either mechanically through fluid dynamics via 3D cavitation or metabolically through active muscle pump actions

Although there was a significant reduction in pain intensity and improvement in arm function in both groups, statistical analysis showed that the functional ability of the arm only increased by less than 10%. This can be explained by the fact that recovery of motor function and muscle working capacity requires a process of tissue structural adaptation as well as restoration of neuromuscular control which requires a longer time (at least 4–6 weeks), compared to pain modulation pathways which work more quickly in the short term (2 weeks). Apart from that, the presence of kinesiophobia factors or movement protection patterns that persist in patients in the healing transition period of 6 therapy sessions is suspected to be the cause of the functional score not changing significantly.

The small average improvement in arm function in this study was likely influenced by the characteristics of the measurement tool used, SPADI. The SPADI disability scale measures complex functional activities involving significant joint loading, such as reaching for high objects or carrying heavy loads. Although the 3D shoulder mobilization and passive-active exercises for three weeks (6 sessions) successfully reduced pain intensity (as recorded on the SPADI pain scale), this duration was insufficient to restore muscle mechanical capacity and address patients' kinesiophobia during daily activities at home. Patients tended to still adopt protective movement patterns during this two-week healing transition period, so scores on the SPADI disability subscale did not show a significant enough decrease to reach the Minimal Clinically Important Difference (MCID) value.

This lag between immediate pain relief and long-term functional recovery is further underscored by contemporary neuro-rehabilitation trials. Modern studies focusing on upper-limb recovery in stroke patients emphasize that while manual therapies significantly resolve joint restrictions, actual motor execution and prehension improvements require sustained

cortical remodelling and task-specific load adaptations. This phenomenon explains why our 3-week time frame fell short of achieving an ideal functional outcome, as structural remodelling and the resolution of protective kinesiophobia cannot be fully accomplished without a chronic training window.

CONCLUSION

The current findings indicate that 3D shoulder mobilization and passive-active shoulder exercises resulted in similar pain improvements during the early post-stroke phase, while functional outcomes did not differ significantly between groups after six treatment sessions. These results should be interpreted as preliminary evidence and highlight the need for further investigation. Future studies should explore modified intervention protocols, varying treatment frequency or intensity, longer intervention periods, and the integration of complementary rehabilitation approaches to determine whether greater functional recovery can be achieved alongside pain reduction.

Limitations of this study were the small sample size and short intervention duration (three weeks), making it difficult to generalize the results. The inclusion criteria, which included arm ability, should have been limited to a single criterion to allow for more clearly discernible improvements in intervention outcomes across the sample. Furthermore, a long-term assessment of the effects is needed, including a post-evaluation six months after therapy is discontinued. The intervention duration can be extended to four or six weeks, and task-specific training interventions can be provided. The SPADI can be used as a measurement instrument but in conjunction with simpler functional assessments such as the FUGL Meyer for Upper Extremity.

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