Galore International Journal of Applied Sciences and Humanities
[Indexed, Peer Reviewed Journal]
Vol. 10; Issue: 2; April-June 2026
Website: www.gijash.com
Research Paper *P-ISSN: 2456-8430*

The Effectiveness of Custom-Made Shoulder Brace in Standing Posture and Gait Variability in Subjects with Post-Stroke Shoulder Subluxation

Dheeraj[1], Fiona Verma[2], Smita Nayak[3]

[1]Prosthetist and Orthotist, Department of Prosthetics and Orthotics, VMMC & Safdarjung Hospital, Ansari Nagar East, New Delhi, India
[2]Prosthetist and Orthotist, Artificial Limbs Centre (ALC), Indian Railway Post Graduate Institute of Medical Sciences and Research & Northern Railway Central Hospital, New Delhi, India
[3]Demonstrator, Department of Prosthetics and Orthotics, Pt. Deendayal Upadhyaya National Institute for Persons with Physical Disabilities, Delhi University, New Delhi, India

Corresponding Author: Dheeraj

DOI: https://doi.org/10.52403/gijash.20260207

ABSTRACT

Background: Hemiplegia is a non-progressive disorder that causes paralysis on one side of the body. Post-stroke hemiplegia often results in shoulder subluxation, impaired posture, and gait abnormalities, which adversely affect functional mobility. Observational studies suggest that orthoses, such as shoulder orthoses, reduce vertical subluxation of the shoulder. Therefore, proper treatment with customized orthotic intervention targeting shoulder stability is more effective for improving shoulder subluxation, to improve posture and gait.
Aims and Objectives: The present study aims to evaluate the effectiveness of a custom-made shoulder brace on standing posture and gait variability in subjects with post-stroke hemiplegia.
Methodology: 15 participants of the age group 40-65 years with post-stroke hemiplegia participated in the study, which was a pre- test post-test experimental study design. The standing posture and gait variability data were evaluated using a posture analysis system. A custom shoulder brace was designed to maintain the shoulder. Pre-test data of posture and gait were evaluated without orthosis. A custom shoulder brace was given to the subjects for 4 weeks, and post- test data were collected.
Results: The results showed a significant improvement in standing posture parameters, including head alignment, ASIS alignment, and lateral trunk alignment, with $p < 0.005$ except in acromion alignment with $p > 0.005$. Gait analysis showed significant improvements in ankle angle, knee angle, hip angle, rear-foot angle, and pelvic drop with $p < 0.005$, except gait variability with $p > 0.005$.
Conclusions: The custom-made shoulder brace demonstrated significant effectiveness in improving posture and gait variability among post-stroke hemiplegic subjects.

Keywords: Post-stroke hemiplegia, GaitOn, Custom- made shoulder brace, Shoulder subluxation, standing posture, gait variability.

INTRODUCTION

Hemiplegia refers to paralysis affecting one side of the body, typically resulting from damage to the brain or spinal cord, with severity varying based on lesion location. Hemiplegia can result from conditions such as stroke, brain infections (by bacteria, fungus, or viruses), brain trauma, brain tumors, and rare mutations in genes [1].

Stroke (cerebrovascular accident) is an acute neurologic illness that displays focal involvement of the central nervous system and is linked to a disturbance of the cerebral circulation [2]. According to the most current Global Burden of Disease (GBD) 2021 stroke burden estimates, stroke continues to be the second most common cause of death (about 7 million) among non-communicable disease burden, and the third most common cause of death and disability globally [3].

Developing countries like India are facing a double burden of communicable and non-communicable diseases, making stroke India's fourth leading cause of death and fifth leading cause of disability [4]. According to the Global Burden of Disease Project, there were 1,175,778 stroke event cases in India in 2016. According to a recent systematic analysis that mostly included cross-sectional research, the annual incidence of stroke in India was estimated to be between 105 and 152 per 100,000 persons [5].

In clinical practice, postural asymmetry and shoulder instability significantly affect rehabilitation outcomes in hemiplegic patients. Stroke frequently has a significant impact on the stability and range of motion of the upper limbs. Spasticity and paralysis are common post-stroke upper arm symptoms that can result in shoulder subluxation, adhesive capsulitis, impingement syndrome, and rotator cuff injuries [6].

Inferior subluxation of the Gleno-humeral joint (GHJ) or Gleno-humeral subluxation (GHS), involves partial displacement of the humeral head relative to the glenoid cavity, frequently leading to pain and functional limitations, is one of the most common consequences in the rehabilitation of hemiplegic stroke patients [7,8].

Clinicians typically choose active rehabilitation, which includes bracing, for stroke hemiplegia [2]. Therefore, Patients with gleno-humeral subluxation (GHS) are often prescribed shoulder supports, commonly referred to as shoulder braces or orthoses. Clinical justifications for prescribing a shoulder brace include, among other things, maintaining a normal gleno-humeral alignment and reducing stress in the passive structures from gravitational force while standing or walking. Shoulder orthoses apply an external tension between the humerus and scapula that pulls the arm upward in order to lessen the strain caused by gravity [8].

Apart from GHS, hemiplegic patients after stroke frequently struggle with balance abnormalities [9]. Deficits in motor, visual, and sensory function, cerebellar lesions, or vestibular dysfunction in hemiplegic patients are some of the primary causes of balance impairment. Post-stroke hemiplegic patients have been shown to have uneven weight distribution, higher weight bearing on the unaffected side, and increased body sway during standing [10]. Therefore, Assessment of posture and balance is an important factor in stroke rehabilitation. In the early stages of stroke rehabilitation, when the upper extremity is still flaccid and arm swing is restricted, an arm sling may have a positive impact on balance. The use of shoulder sling, shoulder cuff, and shoulder brace is still controversial. Limited study shows the potential benefits of the braces in maintaining subluxation [11–14]. So, this study aims to design an effective custom-made shoulder brace and to assess its effectiveness in improving the standing posture and gait variability factors using a posture analysis system in subjects with post-stroke shoulder subluxation.

MATERIALS & METHODS

Selection of subjects: The study was carried out in New Delhi, India. A convenience sample of 15 subjects who voluntarily took part was selected for the study. Out of fifteen subjects that were selected according to the inclusion and exclusion criteria, 12 were male and 3 were female, with a mean age of 47.87±7.09 years (descriptive analysis shown in Table 1).

Study design: Pre-test and Post-test experimental.

Inclusion criteria: Subjects can be both male or female, with an age range between 40-65 years [2], developing hemiplegia after stroke, and standing independently for at least 2 minutes [12]. Subjects should have a clinically subluxated gleno-humeral joint (GHJ) determined by finger palpation [15], spasticity up to 1 or 1+ according to Modified Ashworth Scale (MAS), upper limb should be in stage 1or 2 according to Brunnstrom approach, and Mini-Mental status Score ≥24 [12].

Exclusion criteria: Subjects with any previous surgery in shoulder for the past six months, any open wound or skin irritation, fixed contracture or deformity in the shoulder. Identified cognitive delay or other neurological impairment like seizures, visual impairment, Use of any medication, and Trans cutaneous electrical stimulation (TENS) for pain, Neuropharmacology intervention in the last six months to reduce spasticity, subjects using lower extremity orthosis.

Procedure: The subjects were invited to participate in the research. Participants were reviewed and screened according to the inclusion criteria. The subjects received detailed explanations of the method, and then signed the consent form and consented to participate in the study. The experimental group's pre-interventional data (without the orthosis) were collected for standing posture parameters and gait variability parameters, respectively, using a posture analysis software known as GaitOn as shown in Figure 2 [16]. The measurements for a custom–made shoulder brace were taken. The brace was fabricated and delivered to the subject with instructions to wear the brace for four weeks. The post-interventional data (with the orthosis) for standing posture and gait variability were then collected after 4 weeks.

Design of custom-made shoulder brace: The custom-made shoulder brace as shown in Figure 1 was fabricated using a 3mm polypropylene sheet for the arm shell and an anterior-posterior acromion pad. There were four straps [17], out of which three were made attached to the arm shell, maintaining the shoulder in abduction, internal rotation, and elevation, and another one was used to support the brace with the torso. The straps were fabricated with non-elastic material.

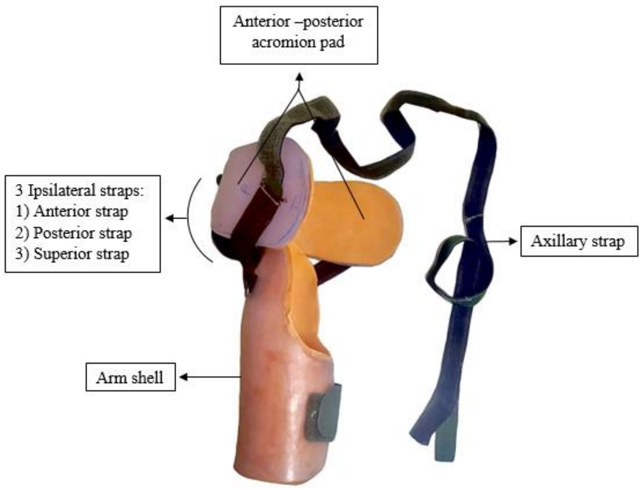
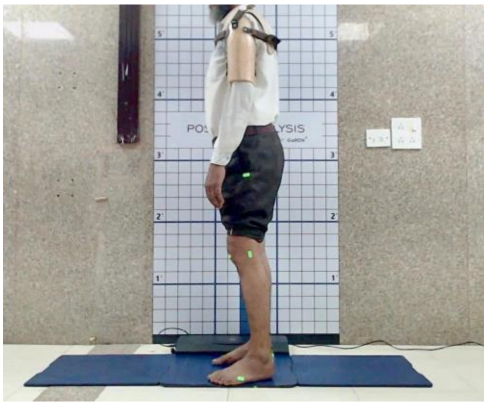


Figure 1. Custom-made shoulder brace

Statistical Technique: Statistical analysis was performed using IBM SPSS version 25.0. Descriptive statistics were used to assess the normality of standing and gait parameters. For standing posture variables, pre–post data of horizontal head alignment, acromion alignment, and lateral trunk alignment were analyzed using the

Wilcoxon signed-rank test, while horizontal alignment of ASIS was analyzed using a paired t-test. For gait parameters, kinematic data were collected to evaluate lower-limb and pelvic motion parameters, including ankle angle, knee angle, hip angle, rear foot angle, and pelvic drop during gait. Paired t-tests were used to compare pre and post values of ankle angle, knee angle, rear foot angle, and pelvic drop, whereas the Wilcoxon signed-rank test was used for hip angle and gait variability factor. The Statistical significance was set at $p < 0.05$.

a Front view assessment



b Lateral view assessment

Figure 2. Performing posture analysis using GaitOn software

RESULT

A total of 15 subjects with post-stroke shoulder subluxation participated in this study. The descriptive statistics of the demographic data are given in Table 1. The table represents descriptive data of age, height, weight, and BMI. The mean and S.D values of age (years) were 47.87±7.09, the mean and S.D values of height (cm) were 161.09±4.37, the mean and S.D values of weight (kg) were 57.67±6.77, and the mean and S.D values of BMI were 22.18±1.85.

Table 1. Descriptive data of Mean age, Height, Weight, and BMI

Subjects' characteristics	No. of participants	Mean ± Std. deviation
Age (in years)	15	47.87±7.09
Height (in cm)	15	161.09±4.37
Weight (in kg)	15	57.67±6.77
BMI	15	22.18±1.85

Standing posture parameters: Changes in standing posture between baseline (without orthosis) and after 4 weeks of shoulder brace use (with orthosis) were analyzed. The pre-post comparisons are given in Table 2 and Table 3. The Wilcoxon signed-rank test was used for horizontal alignment of the head (HAH), horizontal alignment of the acromion (HAA), and lateral trunk alignment (LTA). Significant improvements were observed in HAH (Mean ± S.D = 0.76 ± 0.65 to 2.11 ± 0.27; *p = 0.001)* and LTA (Mean ± S.D = 0.35 ± 0.11 to 1.99 ± 0.35; *p = 0.001)* as shown in Graph 1 and 3, respectively. However, HAA did not show a statistically significant change as shown in Graph 2 with (Mean ± S.D = 0.77 ± 0.56 to 0.53 ± 0.22; *p = 0.15)*. The paired t-test was used to analyze horizontal alignment of the ASIS (HAAS), which showed a significant improvement from Mean ± S.D = 0.49 ± 0.13 to 1.41 ± 0.21 (*p < 0.001)* as shown in Graph 4.

Table 2. Before and after comparison of standing posture parameters using Wilcoxon signed- rank test

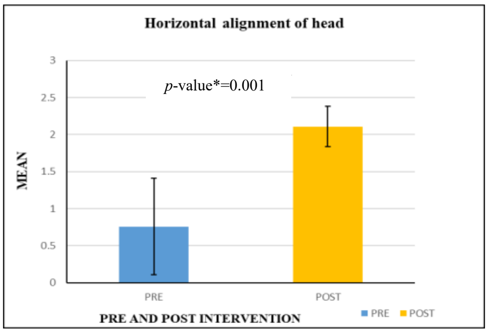
Standing postures parameters	Without orthosis (Mean ± SD)	With orthosis (Mean ± SD)	p-value	z-value
Horizontal alignment of head	0.76 ± 0.65	2.11 ± 0.27	0.001*	–3.297
Horizontal alignment of acromion	0.77 ± 0.56	0.53 ± 0.22	0.15	-1.420
Lateral trunk alignment	0.35 ± 0.11	1.99 ± 0.35	0.001*	-3.414

Values are represented as mean **±SD**
****significant at 0.05 level***

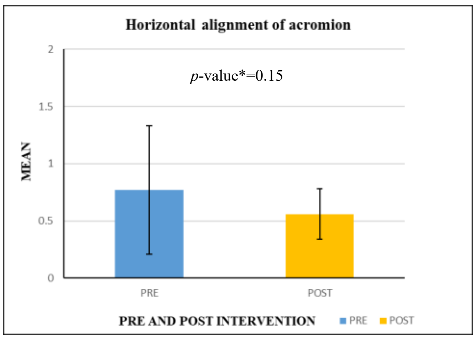
Table 3. Before and after comparison of standing posture parameter using paired t—test

Standing postures parameters	Without orthosis (Mean ± SD)	With orthosis (Mean ± SD)	p- value	t-value
Horizontal alignment of ASIS	0.49 ± 0.13	1.41 ± 0.21	< 0.001*	-15.25

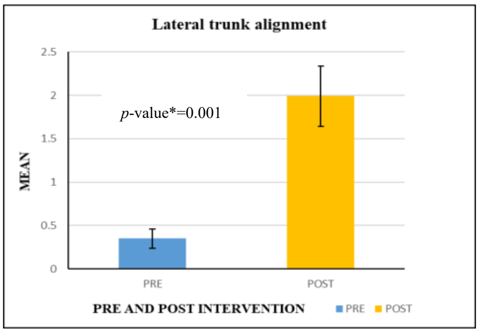
****significant at 0.05 level***



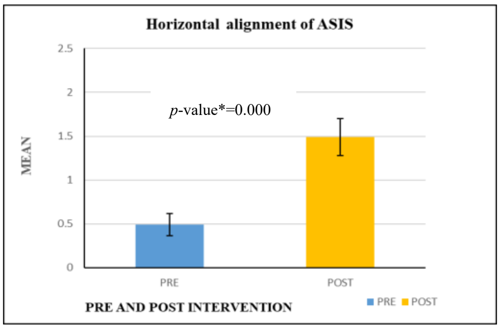
Graph 1. Pre-post result of horizontal alignment of head



Graph 2. Pre-post result of horizontal alignment of acromion



Graph 3. Pre-post result of lateral trunk alignment



Graph 4. Pre-post result of horizontal alignment of ASIS

Table 4. Before and after comparison of gait variability using Wilcoxon signed-rank test

	Without orthosis (Mean ± SD)	With orthosis (Mean ± SD)	p- value	z-value
Gait Variability	6.68 ± 3.24	5.80 ± 0.96	0.36	-0.909

****significant at 0.05 level***

Gait variability parameters: The Wilcoxon signed-rank test was used to evaluate gait variability between pre-intervention (without shoulder brace) and post-intervention (with shoulder brace) conditions in post-stroke participants given in Table 4. The results showed no statistically significant difference between the two conditions. The mean ± SD values changed from 6.68 ± 3.24 at baseline to 5.80 ± 0.96 after 4 weeks of brace use ($p = 0.36$).

Lower limb gait kinematics: Kinematic analysis was performed to evaluate changes in ankle angle, knee angle, hip angle, rear-foot angle, and pelvic drop in the sagittal and frontal plane during the loading response phase of gait in post-stroke participants with pre-post comparison given in Table 5 and Table 6. Paired t-tests were used to analyse ankle angle, knee angle, rear-foot angle, and pelvic drop. Significant improvements were observed after 4 weeks of shoulder brace use compared with baseline. The ankle angle changed from Mean ± S.D =102.21 ± 11.68 to 99.47 ± 10.51 ($p < 0.001$), knee angle from Mean ± S.D =175.73 ± 11.92 to 177.41 ± 12.45 ($p < 0.001$), rear-foot angle from Mean ± S.D = −3.59 ± 1.84 to 3.76 ± 0.73 ($p < 0.001$), and pelvic drop from Mean ± S.D = 2.56 ± 1.19 to 13.19 ± 2.52 ($p < 0.001$). The Wilcoxon signed-rank test was used for hip angle, which showed a significant reduction from 0.23 ± 6.35 to −0.61 ± 6.60 ($p = 0.01$).

Table 5. Before and after comparison of Lower limb kinematic parameters using a paired t-test

Kinematic parameters	Without orthosis (Mean ± SD)	With orthosis (Mean ± SD)	p- value	t-value
Ankle angle	102.21 ± 11.68	99.47 ± 10.51	< 0.001*	6.672
Knee angle	175.73 ± 11.92	177.41 ± 12.45	< 0.001*	-5.904
Rear-foot angle	-3.59 ± 1.84	3.76 ± 0.73	< 0.001*	-15.804
Pelvic drop	2.56 ± 1.19	13.19 ± 2.52	< 0.001*	-25.677

***significant at 0.05 level**

Table 6. Before and after comparison of Lower limb kinematic parameters using Wilcoxon signed-rank test

Kinematic parameters	Without orthosis (Mean ± SD)	With orthosis (Mean ± SD)	p- value	z-value
Hip angle	0.23 ± 6.35	-0.61 ± 6.6	0.01*	-2.559

***significant at 0.05 level**

DISCUSSION

This study aimed to assess the effect of a shoulder brace on standing posture and gait variability in post-stroke individuals with shoulder subluxation. The results revealed significant improvements in multiple postural and kinematic parameters following the use of the brace, indicating its potential role in enhancing postural alignment and gait mechanics in this population. Among the standing posture variables, significant improvements were observed in the horizontal alignment of the head, lateral trunk alignment, and horizontal alignment of the ASIS, whereas the horizontal alignment of the acromion did not show a statistically significant change. These findings align with those of Rania m et al. and Hesse. S et al. indicating that shoulder orthoses can influence global postural control by enhancing proprioceptive input and trunk stability [6,13]. Improved head and trunk alignment may reflect enhanced neuromuscular control through improved postural synergy and weight distribution, which is critical for patients with hemiplegia [9,14]. The non-significant change in acromion alignment suggests that although the brace may assist in shoulder stabilization, its direct impact on scapular positioning at rest might be limited. This could be due to structural limitations or varying degrees of muscle tone and shoulder mobility post-stroke [15]. Matthews MJ et al. also reflects findings that while bracing supports joint positioning, complete alignment correction often requires complementary interventions such as physical therapy [18].

Contrary to expectations, gait variability did not show a statistically significant difference between pre- and post-intervention conditions. While some participants exhibited improved consistency in gait patterns, the group-level change was not sufficient to reach significance. This could be attributed to the multifactorial nature of gait variability, which is influenced by not just postural alignment but also neuromuscular coordination, cognitive status, and sensory feedback [19,20]. Although previous studies from Acar M et al. and Gouelle A et al. have reported that arm slings and shoulder support devices may enhance balance and gait, the short-term application in this study may not have provided sufficient time for motor learning and adaptation to manifest in improved gait regularity. Further longitudinal studies with extended brace use and gait retraining may yield different outcomes [11,14].

Significant improvements were observed in all kinematic parameters assessed during the loading response phase, including ankle, knee, hip, rear-foot, and pelvic drop angles.

Ankle and Knee Angles**:** Both joints showed significant improvements in sagittal plane kinematics, with reduced dorsiflexion and knee flexion during the loading response post-intervention. This suggests that the use of the shoulder brace may have contributed to improved lower limb alignment or control during gait, likely due to enhanced postural stability and weight distribution. The present study aligns with previous researchers, who observed that improved upper body alignment contributes to better lower limb control [9,13]. The improvements may reflect enhanced proprioception and muscle activation efficiency due to improved trunk stabilization via the brace.

Hip Angle**:** The reduction in hip flexion was also statistically significant, suggesting improved dynamic hip control. This is important in the context of post-stroke gait, where compensatory strategies often involve excessive hip flexion during initial contact and loading response. The shoulder brace may have helped in restoring more normalized movement patterns by facilitating proximal stability [8].

Rear-foot Angle (Frontal Plane): The rear-foot angle demonstrated a highly significant reduction, indicating better control over pronation or valgus tendencies during loading response. Spaulding SJ et al. also discovered that upper body alignment, influenced by the brace, can have downstream effects on foot posture and stability [17].

Pelvic Drop (Frontal Plane): The significant reduction in contralateral pelvic drop suggests improved frontal plane pelvic control. Pelvic stability during gait is crucial for weight transfer and balance. These findings were consistent with those of Matuszewsha A et al. who have emphasized the interdependence between shoulder and pelvic girdle control [19]. The results of this study reinforce that targeted shoulder interventions can contribute to more stable pelvic mechanics during gait.

Clinical Implications

The findings of this study provide evidence supporting the clinical utility of shoulder braces not only for joint protection but also for enhancing postural symmetry and improving gait mechanics. The improvements in both upper and lower body alignment parameters suggest that shoulder bracing can play a vital role in comprehensive stroke rehabilitation. These results emphasized the biomechanical influence of upper limb supports on gait and posture [21,22.] However, the non-significant findings related to acromion alignment and gait variability highlight the limitations of using bracing alone and point to the need for multimodal rehabilitation strategies.

Limitations & Future Indications

While the present findings provide useful insights, a few considerations should be noted. The sample size was relatively small, and the follow-up period was limited. Future studies with larger samples and longer follow-up may help further confirm the findings and better understand the longterm effects of shoulder orthosis use, particularly on postures, gait, and balance.

CONCLUSION

This study investigated the effects of a shoulder brace on standing posture, gait variability, and lower limb kinematics in post-stroke individuals with shoulder subluxation. The findings demonstrated that the use of the shoulder brace led to significant improvements in several aspects of standing posture, including horizontal alignment of the head, lateral trunk alignment, and ASIS positioning. Although horizontal alignment of the acromion did not change significantly, the overall postural alignment was enhanced, suggesting a positive influence of the brace on proximal stability.

While gait variability did not show a statistically significant improvement, all lower limb kinematic parameters, including ankle, knee, and hip angles in the sagittal plane, as well as rear-foot angle and pelvic drop in the frontal plane, showed significant positive changes following the intervention. These results indicate that the shoulder brace contributed to more efficient and stable gait mechanics, likely by improving upper body alignment and weight distribution. In conclusion, the shoulder brace demonstrated measurable benefits in postural control and gait kinematics in post-stroke patients with shoulder subluxation. Although not all parameters showed significant change, the overall outcomes support the clinical utility of the shoulder brace as part of a multidisciplinary rehabilitation approach.

Declaration by Authors

Ethical Approval: Approved

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest

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How to cite this article: Dheeraj, Fiona Verma, Smita Nayak. The effectiveness of custom-made shoulder brace in standing posture and gait variability in subjects with post-stroke shoulder subluxation. *Galore International Journal of Applied Sciences & Humanities*. 2026; 10(2): 44-52. *DOI: 10.52403/gijash.20260207*

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