



Effect of Compelled Body Weight Shift (CBWS) Therapy in Comparison to Proprioceptive Training on Functional Balance, Gait, and Muscle Strength Among Acute Stroke Subjects

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Abstract

Background: The majority of poststroke individuals tend to exhibit reduced loading over the paretic lower extremity, leading to increased postural sway, and gait asymmetry predisposing to a higher number of falls. Compelled body weight shift (CBWS) therapy is an innovative method aimed to force body weight shift toward the paretic extremity. Proprioceptive training (PT) is another method that improves balance ability contributing to the increase in muscle activity. Both the CBWS and PT have been shown to improve the quality of life in stroke subjects.

Purpose: The aim of this study is to compare the effects of CBWS therapy and PT in improving balance, kinematic gait parameters, and muscle strength among acute stroke patients.

Methods: Thirty subjects were nonrandomly divided into two groups where both groups received routine physiotherapy for two weeks in addition to which the CBWS group incorporated a 15 mm platform placed under the unaffected extremity while the PT group included incorporated proprioceptive exercises on the ground and foam mat. Functional balance, functional mobility, videographic analysis of degrees of hip flexion, knee hyperextension, and ankle dorsiflexion along with gait speed and spatiotemporal gait parameters were obtained.

Results: The pre-post analysis within both groups revealed statistically significant improvement in all parameters except for the kinematic parameters of gait. However, no statistically significant difference was observed between the CBWS and PT groups.

Conclusion: CBWS can be used as an alternative to PT in the rehabilitation of stroke patients concerning balance and gait. CBWS provided during active treatment sessions results as effective as those seen as a result of all-day therapy.

Keywords

Acute stroke, balance, CBWS, compelled body weight shift therapy, closed kinematic chain (CKC), constrained weight shift training, gait, muscle strength, proprioceptive training

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Introduction

Stroke among adults is one of the principal causes of serious and long-term disability.¹ Approximately 88% of individuals with acute stroke hemiparesis have poor voluntary control of movements resulting in motor disability.^{2,3} There is an increased risk of falls along with dependency for daily living activities for individuals with balance deficits.³

Studies have shown that one of the important contributors to efficient ambulation is the symmetry of stance and

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weight-bearing.² The majority of the acute stroke patients exhibit reduced loading of the paretic lower extremity causing increased postural sway in a quiet stance. These are further followed by faulty anticipatory postural adjustments to body perturbations predisposing stroke patients to higher fall risk.^{4,5} Weight-bearing asymmetry results in gait abnormalities like prolonged swing phase and shortened single-limb support time on the paretic extremity because of the compensatory movement patterns known as learned disuse.^{5,6} Gait asymmetry might induce overloading of the unaffected extremity restricting daily function and ambulation within the community.⁵ Continued asymmetrical weight-bearing may encourage further disuse of the paretic extremity.⁷ Although various treatment approaches and assistive devices are available to achieve ambulation in stroke patients such as ankle-foot orthosis for the paretic lower extremity to provide stability to the ankle and knee joint^{2,8} and body-weight supported treadmill training for early mobilization.^{2,9,10} These techniques have not shown significant improvement in weight-bearing symmetry among stroke patients.^{11,12}

Compelled body weight shift (CBWS) therapy is an innovative technique that uses a shoe wedge or lifts under the nonparetic lower extremity forcing stroke patients to shift their body weight toward the paretic extremity. Thereby gradually helping the individual to overcome the phenomenon of learned disuse on the paretic side.^{2,7} Studies have made use of lateral-wedged insoles,^{6,8} and D-shaped insole made of polyvinyl chloride materials² of various heights as a part of CBWS therapy. A shoe lift of 10 mm when coupled with balance exercises showed significant improvement in the stride length, gait speed, and weight-bearing symmetry among chronic stroke individuals.¹³ In acute stroke individuals, a shoe lift of 6 mm in addition to conventional therapy resulted in weight-bearing, balance, and gait velocity improvement.⁷

Proprioceptive and kinesthetic dysfunctions are other impairments seen in stroke patients.¹⁴ Proprioception recovery is considered to be an important factor for rehabilitation to prevent functional limitations in individuals with stroke.¹⁵ Studies have shown that proprioceptive control programs improved the quantitative gait parameters and balance leading to increased muscle activity eventually improving joint stability among chronic stroke individuals.¹⁶ Improvement in muscle strength and proprioceptive control is because of the closed kinematic chain (CKC) exercises of the lower extremity that induces compressive forces over the joints.¹⁷ Prowling is compelled ambulation with a minimum of 15 to 20 degrees of knee flexion. A study conducted by Dalal et al. used proprioceptive training (PT) along with prowling as a part of CKC exercises for the affected lower limb which revealed improved gait parameters in terminal ranges of knee extension.¹⁸

Even with the availability of literature describing CBWS and proprioceptive therapy, there is a dearth of literature comparing their effects on balance, gait, and muscle strength among stroke patients. Therefore, the present study analyses and compares the

effects of CBWS versus PT in improving balance, gait, and muscle strength among individuals with acute stroke.

The primary aim of this study was to compare the effectiveness of CBWS therapy and PT on functional balance, velocity, and kinematic parameters of gait on stroke individuals using specific balance assessment and video graphical analysis. The secondary aim was to associate the strength gains in the affected lower extremity with gait and balance parameters.

Methods

Participants

This study was conducted in Kasturba Medical College (KMC) Hospitals Mangalore, Manipal Academy of Higher Education, India. Inclusion criteria were: subjects with a single episode of stroke who were clinically stable, with an ability to walk five meters without support (with or without assistive devices), age group of 20 to 80 years, Brunnstrom recovery staging for lower limb ≥ 3 , mini-mental state examination score >23 . Exclusion criteria were: any concurrent neurological disorders such as Alzheimer's, Parkinson's disease, hemineglect, and pushers syndrome, and severe visual field defects such as hemianopia and somatosensory deficit, severe plantar flexor tightness, and any cardiopulmonary conditions interfering with the rehabilitation.

The sample size was estimated to be 30 (15 in each group) with 85% power of the study, 95% confidence interval and with mean, standard deviation, and mean differences based on a previous study.¹⁹ Approval for the study was granted by

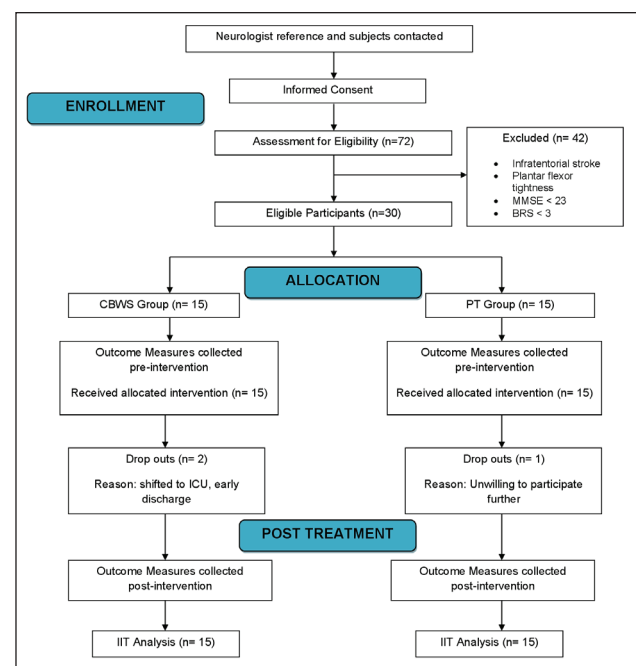


Figure 1. Consort flowchart.

the Institutional Ethics Committee (IEC) KMC Mangalore, Manipal Academy of Higher Education, Manipal, India (IEC KMC MLR 11-18/413), and the selection procedure is illustrated as shown in Figure 1 and informed consent was taken from interested subjects. Postscreening the eligible subjects based on exclusion and inclusion criteria has explained the purpose of the study. The demographic data for each subject were assembled and subjects were assigned nonrandomly to either group.

Procedure

The subjects gait was videotaped using the GoPro Hero5 HD camera (resolution of 4000×3000 pixels and a frame rate of 60 frames/s), placed on a Benro T600EX tripod stand with a spirit level, and kept at a perpendicular distance from the midpoint of the 5-m walkway with its height corresponding to the level of the knee joint. The specific distance was marked using duct tapes. The greater trochanter, lateral condyle of the femur, lateral malleolus of the fibula, and head of the fifth metatarsal of the subject's paretic extremity were marked using reflective markers. The ambulation of the subject of five meters distance with or without support was recorded. Postcapture of videos, analysis of the gait, was done using Kinovea video analysis software by freezing each stance phase of the gait cycle. The components included were degrees of hip flexion, knee hyperextension, and ankle dorsiflexion along with the total time taken to complete a

walking distance of 5 m. For functional balance, Brunel balance assessment (BBA) was used, functional mobility, timed up and go (TUG) test was used, and for spatiotemporal aspects of gait Wisconsin gait scale (WGS) was used (details of the scales added as an appendix). The muscle strength of the quadriceps muscle was calculated with the handheld dynamometer. All the above-mentioned parameters were randomly applied to minimize the possibilities of any carryover effect and the measurements were recorded by an independent blinded assessor pre and postintervention.

Intervention

The entire treatment consisted of a total of 12 sessions spanning for two weeks (six days per week) with approximately one h of conventional physiotherapy consisting of an active-assisted range of motion exercises, strengthening exercises, postural correction exercises, functional reeducation with transitions such as sit-to-stand and stepping activities and gait training with and without assistive devices per session as followed in KMC hospitals. As an adjunct, the CBWS therapy group used a platform with a height of 15 mm secured using Velcro straps which was placed under the unaffected lower extremity while performing standing exercises, sit to stand transitions, and during walking which lasted for 10 to 20 min (shown in Figure 2). The PT group received proprioceptive exercises such as partial squats, single limb stance with or without support, single limb partial



Figure 2. CBWS therapy with 15mm platform under unaffected lower extremity.



Figure 3. Proprioceptive training with single limb stance on ground.



Figure 4. Proprioceptive training with single limb stance on foam.

squats stance on the ground (shown in Figure 3), and a foam mat (shown in Figure 4). The intensity and progression were based on the subject's capacity with every set performed for a minimum of three to five repetitions and a maximum of 15 repetitions, with a hold time of 3 to 10 s, wherever applicable.

Data Analysis

The collected data was coded and entered on a statistical package for the social sciences version 25.0 for analysis. The results were expressed as proportion and median with the interquartile range using appropriate tables and figures. Comparison across the groups was performed using Wilcoxon's signed-rank test and Mann-Whitney *U* test. Intention to treat analysis was used for this study. A "*P*" value of $< .05$ was considered statistically significant for the above test.

Results

The 30 subjects included were allocated to CBWS ($n = 15$) and PT groups ($n = 15$) underwent a similar stroke protocol followed by the hospital postadmission which included antihypertensive, antiepileptic, and antidiabetic medications. The baseline characteristics of the variables: age, gender, Brunnstrom recovery staging, risk factors including the presence of comorbidities, poststroke duration, and type of stroke are shown in Table 1, which showed no statistically significant difference across the groups.

The baseline values of balance, gait, and quadriceps muscle strength showed no statistically significant difference between the CBWS and PT groups. For within-group analysis shown in

Tables 2 and 3, both the groups showed a statistically significant difference in parameters of BBA and TUG. WGS and quadriceps muscle strength did not show a statistically significant difference in the kinematic parameters of gait ($P > .05$) except for gait speed in the CBWS group. There was a statistically significant improvement in functional balance on BBA in CBWS ($P = .001$) and PT groups ($P = .003$). A similar trend was observed in the functional mobility using TUG in CBWS group ($P = .001$) and PT group ($P = .008$), spatiotemporal gait parameters using WGS in CBWS group ($P = .001$) and PT group ($P = .002$) along with quadriceps muscle strength in CBWS group ($P = .002$) and PT group ($P = .004$).

Across the group, the analysis revealed that both the CBWS group and the PT group in Table 4 showed improvements in functional balance, functional mobility, kinematic and spatiotemporal gait parameters, and muscle strength but did not show a statistically significant difference between both the CBWS and PT groups ($P > .05$).

Discussion

Stroke potentially leads to weight-bearing asymmetries caused because of motor weakness, tone asymmetry, and somatosensory deficits which affect the functional activities of poststroke patients.⁷ The current study investigated the use of CBWS therapy incorporating a lift or platform under the nonparetic lower extremity only during the therapy sessions to minimize the weight-bearing asymmetry and to observe its effects on balance, gait symmetry, and muscle strength among acute stroke subjects when compared to PT. A prior study on healthy individuals with the application of a shoe insole under one lower extremity demonstrated asymmetry in the position of the pelvis leading to forced weight-bearing over the other extremity.¹⁹

According to Aruin et al., a disadvantage is observed with a shoe lift of 25 mm causing limb-length discrepancy leading to stress fractures in the affected lower extremity.¹³ In the earlier studies, a shoe lift height within 10 mm under the nonparetic lower extremity showed positive changes in weight-bearing symmetry, balance, and gait among stroke patients.^{7,13} In the present study, we have used a platform height of 15 mm which eliminates the possibility of limb-length discrepancy and its associated disadvantages. Acute stroke patients in our study ranged from above and below 40 years, although the subjects included in the study were of a wider range, the baseline characteristics between both the groups had no statistically significant difference between them.

In our study, the CBWS group revealed statistically significant improvement in functional balance, functional mobility as well as qualitative gait parameters across time. Functional balance on BBA had a mean change score more than the MCID value proving clinically significant improvement in both the CBWS and PT groups.²⁰ The probable reason for the improvement in functional balance

Table 1. Baseline Demographic Data (*n* = 30)

Variables [€]		CBWS Group n (%)	PT Group n (%)	P Value
Age	20–40	1 (33.3)	2 (66.6)	0.82
	40–60	8 (53.3)	7 (46.6)	
	60–80	6 (50.0)	6 (50.0)	
Gender	Male	7 (41.1)	10 (58.8)	0.27
	Female	8 (61.5)	5 (38.4)	
Risk factors	Present	13 (52.0)	12 (48.0)	0.62
	Absent	2 (40.0)	3 (60.0)	
Type of stroke	Ischemic	13 (48.1)	14 (51.8)	0.54
	Hemorrhagic	2 (66.6)	1 (33.3)	
BRS	3 toward 4	2 (66.6)	1 (33.3)	0.87
	4 toward 5	6 (42.8)	8 (57.1)	
	5 toward 6	6 (54.5)	5 (45.5)	
	6	1 (50.0)	1 (50.0)	
Affected side	Right	9 (52.9)	8 (47.1)	0.71
	Left	6 (46.1)	7 (53.8)	
Poststroke duration (days)	1–10	13 (52.0)	12 (48.0)	0.83
	11–20	1 (33.3)	2 (66.6)	
	21–30	1 (50.0)	1 (50.0)	

Abbreviations: [€], Chi-square test; n, number; CBWS, compelled body weight shift; PT, proprioceptive training; BRS, Brunnstrom recovery stage.

Table 2. Pre-Post Intervention Difference for Outcome Variables Among the CBWS Group

Characteristics [€]	Prevalues	Postvalues	P Values
	Median (IQR)	Median (IQR)	
BBA	7.00 (5.25, 10.00)	9.50 (8.00, 12.00)	0.001*
TUG	24.50 (22.00, 28.75)	22.50 (16.50, 26.75)	0.001*
Hip flexion degree	17.00 (15.00, 20.00)	18.00 (15.00, 20.00)	0.48
Knee hyperextension degree	-5.50 (-11.75, 0.50)	-7.00 (-11.75, -4.00)	0.48
Ankle dorsiflexion	15.50 (12.00, 18.75)	16.00 (13.00, 18.00)	0.58
Total time taken	35.50 (29.00, 46.75)	29.00 (25.25, 37.25)	0.001*
WGS	23.50 (18.25, 27.75)	17.50 (15.00, 23.75)	0.001*
Quadriceps strength	3.00 (3.00, 4.75)	4.00 (3.00, 5.00)	0.02*

Abbreviations: [€], Wilcoxon signed-rank test; IQR, interquartile range; BBA, Brunel balance assessment; TUG, timed up and go test; WGS, Wisconsin gait scale; *, significant.

on BBA could be because of the improvement in weight-bearing symmetry forcing the center of gravity to the midline. This further facilitated symmetry in performing transitions like sit-to-stand concurred in an earlier work by Mohapatra et al., on weight-bearing symmetry and balance.⁷ A similar trend of improvement was observed in all the components of the BBA scale following PT on stable and unstable surfaces. One possible reason could be forced weight-bearing over the paretic extremity facilitates load receptor feedback to the central nervous system thereby resulting in improved joint stability, postural control, and balance.^{15,21}

Improvements in functional mobility are considered to be one of the predictors for improved gait.^{2,6} Our study assessed functional mobility using the TUG test which showed statistically significant improvements across time in both groups but failed to show a clinically significant change (MCID < 2.9 s).²² Forced weight-bearing over the paretic lower extremity during dynamic activities including sit-to-stand transitions along with ambulation in the CBWS group, increased the capacity to translate it during walking further improving functional mobility.²³ In PT, earlier works showed that increased weight-bearing symmetry stimulates spatial positional sense in the lower extremity and the capacity to

Table 3. Pre-Post Intervention Difference for Outcome Variables Among the PT Group

Characteristics [€]	Prevalues Median (IQR)	Postvalues Median (IQR)	PValues
BBA	7.50 (6.00, 9.75)	10.00 (8.25, 12.00)	0.003*
TUG	24.00 (18.25, 27.50)	22.50 (16.25, 27.25)	0.008*
Hip flexion degree	18.00 (15.00, 21.00)	20.50 (16.25, 23.00)	0.06
Knee hyperextension degree	-6.00 (-12.00, 2.75)	-11.00 (-16.50, -4.00)	0.08
Ankle dorsiflexion	17.00 (13.00, 19.75)	14.00 (11.25, 18.00)	0.53
Total time taken	32.00 (25.25, 42.75)	27.00 (20.50, 37.50)	0.16
WGS	21.50 (17.25, 27.75)	18.50 (15.50, 21.50)	0.002*
Quadriceps strength	2.00 (1.00, 4.00)	4.00 (2.00, 5.00)	0.004*

Abbreviations: [€], Wilcoxon signed-rank test; IQR, interquartile range; BBA, Brunel balance assessment; TUG, timed up and go test; WGS, Wisconsin gait scale; *, significant.

Table 4. Change Scores of CBWS and PT Groups

Characteristics [¥]	CBWS group Median (IQR)	PT Group Median (IQR)	PValue
BBA	2.0000 (1.0000, 3.0000)	1.0000 (0.0000, 3.7500)	0.45
TUG	-2.0000 (-4.0000, -1.0000)	-2.0000 (-3.7500, 0.0000)	0.29
Hip flexion degree	0.0000 (-3.0000, -4.7500)	0.5000 (-0.7500, 4.0000)	0.25
Knee hyperextension degree	0.0000 (-4.7500, 1.7500)	-3.0000 (-6.5000, 0.0000)	0.59
Ankle dorsiflexion	0.0000 (-1.7500, 2.7500)	0.0000 (-4.7500, 0.7500)	0.36
Total time taken	-6.0000 (-6.7500, -3.0000)	-4.5000 (-5.7500, 0.0000)	0.38
WGS	-4.0000 (-5.7500, -3.0000)	-3.0000 (-5.5000, -0.2500)	0.24
Quadriceps strength	0.5000 (0.0000, 1.0000)	1.0000 (0.0000, 2.0000)	0.36

Abbreviations: [¥], Mann–Whitney *U* test; CBWS, compelled body weight shift; PT, proprioceptive training; IQR, inter quartile range; BBA, Brunel balance assessment; TUG, timed up and go test; WGS, Wisconsin gait scale; Level of significance ($P < .05$).

support body weight further enhancing postural control, balance, and gait and the same might be the plausible reason for the improvement of functional mobility in the PT group.^{3,15} According to prior studies^{1,3,15,24} on stroke patients, an improvement in gait velocity or cadence would not necessarily indicate an improvement in all spatial parameters of gait.

Qualitative parameters of gait such as the spatiotemporal parameters using WGS revealed statistically significant improvement in either group across time. The improved weight-bearing symmetry induced by the CBWS platform might have reduced circumduction gait, excessive weight shift to the nonparetic side, a tendency for hip hiking, and a wide base of support while ambulating,²⁵ resulting in improved WGS parameters. This could have concurred in a prior study where the application of a textured insole under the nonparetic lower extremity showed improvements in stance and swing symmetry of gait among stroke patients.²⁶ On the other hand, improvements in the PT group could be attributed to the CKC exercises that stimulate the mechanoreceptors inducing enhanced joint position sense and proprioceptive control during terminal knee extension

ranges facilitating near normal gait patterns explaining the probable mechanism of improvement.¹⁷ Visual inspection of the raw data of the kinematic gait parameters revealed betterment in the angle of hip flexion, knee hyperextension, and ankle dorsiflexion except for the angle of ankle dorsiflexion in the PT group. However, these changes were not statistically significant across time. A prior study that used prowling as compelled ambulation technique with a minimum of 15 to 20 degrees of knee flexion along with PT observed reduced knee hyperextension and improved hip flexion and ankle dorsiflexion angles in kinematic parameters of gait.¹⁸ The weight-bearing symmetry in the CBWS group might have helped in better recruitment of muscles of the paretic extremity leading to improved muscle strength. A similar pattern was found between paretic extremity quadriceps muscle strength and weight-bearing symmetry in chronic stroke subjects by Lamoglio²⁷ and by Chae et al.¹⁵ Improvements in muscle strength within the PT group could be attributed to the mechanoreceptor facilitation with CKC exercises which would further increase load-receptor facilitation to the cortex.²¹

The limitations of our study were the inadequate shorter treatment duration was not enough to show changes in the kinematic parameters of gait in both groups suggesting that a longer duration of intervention would facilitate positive changes. Second, the lack of follow-up could not measure the long-term effects between both the groups. Third, most of the acute stroke subjects belonged to the age groups above 40 years, making it was difficult to generalize the results to the younger stroke population. Further studies should include analysis of the effects of various heights of platforms used in CBWS therapy in comparison to other interventions. In addition to this, the effects of long-term therapy on the kinematic gait parameters should be further analyzed.

Conclusion

This study showed improvements in functional balance, functional mobility, muscle strength, and qualitative gait parameters across time within both the CBWS group and PT group. However, no statistically significant improvement was observed when CBWS therapy was compared with PT suggesting CBWS with a platform of 15 mm can be an alternative to PT in the rehabilitation of individuals with acute stroke with regard to balance and gait. Also, CBWS provided during active treatment sessions showed results as effective as those seen as a result of all-day therapy.

Appendix

Functional Balance Assessed Using BBA

It integrates both static and dynamic balance training to maintain or improve activities of daily living and quality of life. The BBA is a 14-point hierarchy of dynamic tasks including supported sitting and standing balance and walking along with step-ups. Test-retest reliability is 0.93 to 0.99. Inter-rater reliability is 100%.

Qualitative Gait Parameters Assessed Using WGS

It is used to assess deviations in gait poststroke. The 14 observable variables are measured to test the spatiotemporal parameters of the gait phase. The score ranges between best at 14 and least at 45. It provides the information required to prepare a customized rehabilitation program and monitor pre-post intervention changes in gait.

Videographic Analysis Using Kinovea Software

The Kinematic parameters of gait consisted of the mean joint angles of the hip, knee, and ankle which were analyzed using the Kinovea software.

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Authors' Contribution

AL was the principal investigator of this study. The conceptualization and study design were by AMJ. Supervision of the trial and data collection was done by AN. The study was designed and the data analysis was executed by PM. Both ZM and SP provided critical inputs and aided with data management. All the authors of this study have equally contributed to the preparation and editing of this manuscript.

Statement of Ethics

This study was conducted after receiving approval from the Institutional Ethics Committee, Kasturba Medical College Mangalore, Manipal Academy of Higher Education (IEC KMC MLR 11-18/413) and registered with the Clinical Trials Registry of India (CTRI/2019/01/016982).

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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