Effects of Compelled Body Weight Shift Therapy on Weight-Bearing Symmetry, Balance and Gait in Patients with Stroke: A Narrative Review

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ABSTRACT: Background: Post-stroke patients exhibit reduced loading over the paretic lower extremity, leading to increased postural sway, balance, and gait asymmetry predisposing to falls. Achieving stance and weight-bearing symmetry are essential contributors in achieving independent ambulation. Compelled body weight shift (CBWS) uses shoe inserts under the non-paretic lower extremity forcing the individual to shift the bodyweight towards the paretic extremity. It facilitates the individuals to overcome the phenomenon of learned disuse and improves weight-bearing symmetry.

Purpose: To consolidate evidence regarding the use of CBWS training in achieving weight-bearing symmetry, improving balance, and gait in stroke patients.

Methods: A comprehensive search was conducted on five databases (PubMed, ClinicalKey, Proquest, ScienceDirect, and Cochrane databases) using predefined MeSH terms. Randomized and non-randomized controlled and clinical trials in the English language published between 2011 and 2021 were retrieved.

Result and Discussion: Studies compared the application of shoe inserts of various heights during conventional stroke rehabilitation and their effect on weight-bearing symmetry, balance, and gait. Studies revealed increased weight-bearing on the paretic lower extremity and increased balance performance. Improvement was noted in spatiotemporal parameters of gait; mainly step length, single support stance time, and gait velocity.

Conclusion: CBWS using shoe lifts and wedges of different heights under the non-paretic lower extremity during conventional stroke rehabilitation effectively improved weight-bearing symmetry. Shoe lifts were effective in improving balance and weight-bearing symmetry, whereas the use of shoe wedges led to improvements in spatiotemporal gait parameters because of the additional subtalar eversion provided by the wedge.

KEY WORDS: Stroke, CBWS, compelled body weight shift therapy, constrained weight shift training, balance, weight-bearing symmetry, gait

ABBREVIATIONS: A-P sway, Anterior–Posterior sway; **AFO**, ankle foot orthosis; **BBS**, Berg balance scale; **CBWS**, compelled body weight shift; **CIMT**, constraint induced movement therapy; **CWST**, constrained weight shift training; **I-ShoWS**, insole shoe wedge and sensors; **M-L sway**, Medial–Lateral sway; **SSSI**, single support symmetry index; **STSI**, stance symmetry index; **SWSI**, swing symmetry index; **TUG**, timed up and go; **6MWT**, 6 meter walk test; **10MWT**, 10 meter walk test

I. INTRODUCTION

Stroke is the foremost cause of serious long-term disability among adults.[1] Approximately 88% of acute stroke patients present with poor voluntary control of movements resulting in motor disability.[2] The impaired balance, postural sway, disordered gait, and augmented probability of falls may be due to motor weakness, asymmetric muscular tone, and somatosensory deficits in the lower extremities. Disturbance in balance increases the risk of falls and dependence on activities of daily living.[3] Stroke patients tend to exhibit reduced loading on the paretic lower extremity, increased postural sway during quiet stance along with faulty postural adjustments to body perturbations and impaired equilibrium reactions.[4] Impaired weight-bearing symmetry results in gait dysfunction due to the compensatory movement patterns known as learned disuse, which may promote further disuse of the paretic lower extremity.[5,6]

Achieving stance and weight-bearing symmetry are considered to be important contributors in attaining the goals of ambulation.[2] Several treatment strategies such as ankle–foot orthosis (AFO),[7] bodyweight supported treadmill training,[8,9] and placement of the non-paretic lower limb on a step have been used for improving weight-bearing symmetry over the paretic side during stance and correct abnormal gait pattern among stroke patients.[7,10,11]

Compelled body weight shift (CBWS) therapy utilizes a shoe lift or wedge, forcing the individual to shift their bodyweight toward the paretic extremity, and gradually facilitates the individual to overcome the phenomenon of learned disuse of the paretic leg. Such a compelled redistribution of body weight resembles the concept of "forced use" of the paretic extremity.[2,6] Studies have reported that forced use along with functional training of the paretic side demonstrates the principles of neuroplasticity and contributes to improvement in function.[2]

Therefore, the purpose of this narrative review is to consolidate evidence regarding the use of CBWS therapy in achieving weight-bearing symmetry, improving balance, and gait in stroke patients. In this review, both the terms compelled bodyweight shift therapy and constrained weight shift therapy are considered similar.

II. METHODOLOGY

A. Initial Article Identification

A comprehensive search was conducted to identify relevant studies on PubMed, ClinicalKey, Proquest, ScienceDirect, and Cochrane databases. The search combined the following terms: ("compelled body weight shift therapy" OR "constrained weight shift therapy") AND ("stroke" OR "CVA" OR "cerebrovascular accident") AND ("balance") OR ("gait") OR ("weight-bearing symmetry").

Inclusion criteria were defined based on population, intervention, comparison, and outcome (PICO) assessing patients with stroke aged 18 and older. Criteria included 1) randomized control or clinical trials (RCTs) and non-randomized control or clinical trials (NRCTs); 2) studies with compelled body weight shift therapy or constrained body weight shift therapy; 3) interventions targeting weight-bearing symmetry, balance, and gait; and 4) full-text articles between 2011 and 2021 in the English language. Figure 1 summarizes the selection procedure.

B. Quality Assessment

A methodological rating of each study was assessed using the Physiotherapy Evidence Database scale (PEDro) for RCTs comprising 11 components requiring simple yes or no responses. The maximum score awarded is 10 (the first component not included in the total score). The rating was carried out by author AL and scrutinized by AN. One study scored 8, five studies scored 7, three studies scored 6, four studies scored 4, and one scored 3 on the PEDro scale. Table 1 summarizes the methodological rating for each of these studies.

A data extraction table was created to cover all data regarding the objectives of this review. Data was organized to highlight study characteristics and effects of CBWS on various outcomes, namely weight-bearing symmetry, balance, and gait.

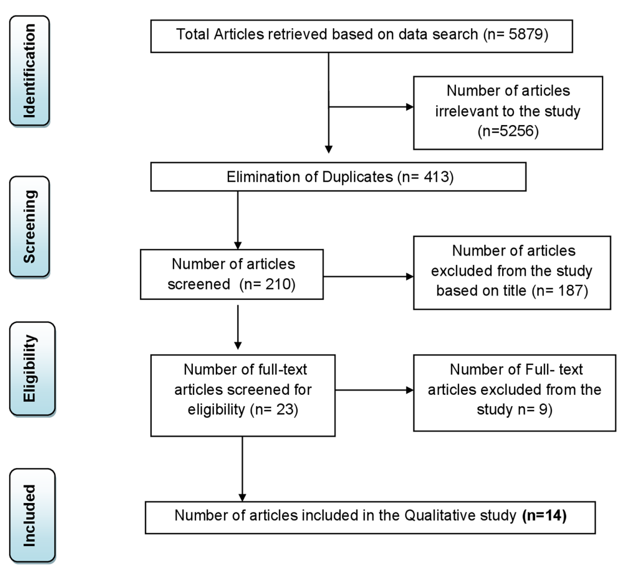

Fig. 1: Data extraction flowchart

TABLE 1: Rating of articles on PEDro

Criteria	Sungkarat et al.[12] 2010	Aruin et al.[1] 2012	Mohapatra et al.[6] 2012	Sheikh et al.[15] 2016	Yu et al.[5] 2015	Kang et al.[18] 2015	Elsayed et al.[13] 2016	Nam et al.[16] 2017	Son[19] 2017	Ma et al.[26] 2018	Aruin et al.[17] 2018	Liao et al.[20] 2018	Krishna et al.[14] 2018	Fortes et al.[25] 2020
Eligibility criteria were specified	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Random allocation to groups	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Allocation was concealed	Yes	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No
Baseline comparability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Blinding of all subjects	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes	No
Blinding of all therapists	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Blinding of all assessors	Yes	No	No	Yes	Yes	No	No	No	No	No	No	Yes	Yes	No
Adequate follow-up	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	No	No	Yes	Yes	No
Intention to treat	No	No	No	No	No	Yes	No	No	Yes	No	No	Yes	Yes	No
Between-group comparisons	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Point estimates and variability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
TOTAL SCORE	7/10	4/10	6/10	7/10	7/10	6/10	6/10	3/10	7/10	4/10	4/10	8/10	7/10	4/10

III. RESULTS

A total of 5,879 articles were retrieved based on the search strategy, following which 5,256 irrelevant and 413 duplicates were removed. After screening the title and the abstract, 23 articles were selected of which 9 studies were excluded due to inappropriate study design; studies that evaluated outcomes other than weight-bearing symmetry, balance, and gait; and studies published in languages other than English. A total of 14 articles that met the inclusion criteria were included for review, and the details of these individual studies are mentioned in Table 2.

A. Effects of CBWS on Weight-Bearing Symmetry

The percentage of total body weight on the paretic lower extremity was evaluated with the help of a digital weighing scale where patients were asked to stand with their paretic lower extremity on the scale while the non-paretic lower extremity was placed on a wooden plank of similar height.[6,12–14] A few studies also used force platforms to evaluate plantar pressure on the paretic lower extremity.[1,15–17]

1. On Post Stroke Duration

One study assessed the effects of CBWS in acute stroke patients (less than 20 days), and the results revealed a marginal change in weight-bearing symmetry in the experimental group compared to the control group (effect size of 5.09).[6]

Eight studies[1,13,15,17] evaluated the effects of CBWS on weight-bearing symmetry in chronic stroke patients, where three studies[1,15,17] assessed the carry-over effects at various follow-up time intervals. The patients in the experimental group showed a marked change in weight-bearing on the paretic extremity post-treatment compared to the control group (effect size of 0.43), and there was no carry-over effect of the same at four-month follow-up in both groups (effect size of 0.53).[17] However, in two studies,[1,15] there was a significant change both post-treatment and at three-month follow-up (effect size of 1.63 and 1.97, respectively). Another study had an observable change in weight-bearing of paretic extremity in the experimental group post-treatment (effect size of 0.75).[13]

Among the studies included, three studies enrolled both acute as well as chronic stroke patients.[12,14,16] The patients in the experimental group had a significant improvement in weight-bearing symmetry post-intervention when compared to the control (effect size > 0.8),[12,14,16] with a carry-over effect at three weeks (effect size of 0.78), six and nine weeks (effect size > 0.8).[14]

2. Type of Shoe Inserts: Lifts and Wedges

Application of shoe lift as a part of CBWS was reported in seven studies[1,6,13–17] and one study used a seven-degree lateral shoe wedge under the paretic lower extremity[12]; a significant improvement was noticed in weight-bearing symmetry in the experimental

TABLE 2: Summary of the studies included in the review

Author/type of study	Sample size/ study patients/ Intervention duration	Intervention	Outcome measures	Results
Aruin et al.[1] 2012 RCT	$n = 18$ chronic stroke Six weeks for 60 minutes	Experimental Group ($n = 9$): 0.6 cm shoe lift under the non-paretic lower extremity during conventional physical therapy Control Group ($n = 9$): Strengthening exercises, sit to stand maneuvers, weight-bearing exercises, pre-gait training like stepping and gait training with assistive devices	Weight-bearing symmetry: Computerized force platform system. Balance: BBS Gait Velocity: 10MWT At six weeks and three-month follow up	Improvement in weight-bearing symmetry from 35.7 ± 2.3% to 45.4 ± 2.6% at six weeks and to 49.2 ± 3.2% at three months in the experimental group and 33.4 ± 2.8% to 39.6 ± 2.64% at six weeks and 42.2 ± 3.9% at three months in a control group with no statistical significance between the groups ($p = 0.07$) Improvement on BBS from 42.9 ± 3.7 to 45.0 ± 41 at six weeks and 44.8 ± 4.0 at three months in the experimental group. Control group from 33.2 ± 3.5 to 34.0 ± 3.5 at six weeks to 37.7 ± 3.4 at three months with no statistical significance between the groups ($p = 0.08$) Improvement on gait velocity from 0.43 ± 0.1 m/s to 0.48 ± 0.7 m/s at six weeks and 48.8 ± 0.7 m/s at three months. Control group from 0.36 ± 0.89 to 0.36 ± 0.8 m/s at six weeks and 0.34 ± 0.7m/s at three months with no statistical significance between the group
Yu et al.[5] 2015 RCT	$n = 21$ acute and chronic stroke Two weeks for 90 minutes.	Experimental Group (FUT) ($n = 11$): five-degree wedged insole under the non-paretic lower extremity during conventional physical therapy Control Group (CPT) ($n = 10$): Gait training with stepping and obstacle walking, postural training, treadmill training and sit to stand maneuvers	Gait parameters using GAITRite: PWV, FWV, SSI TSI. Gait Velocity: TUG. At two weeks and one-month follow-up	Statistically significant improvement in most of the gait parameters in FUT group when compared to CPT group: (PWV, $p < 0.001$; FWV, $p < 0.01$; TUG: $p < 0.05$) at two weeks Significant changes were seen at one-month follow-up in the FUT group when compared to CPT (PWV, $p < 0.001$; FWV, $p < 0.05$) with no statistically significant change on TUG ($p = 0.98$) Symmetrical walking was seen in the FUT group at FWV when compared to the CPT group

TABLE 2: (*continued*)

Mohapatra et al.[6] 2012 RCT	$n = 11$ acute stroke Two weeks for 90 minutes	Experimental Group ($n = 5$): 0.6 cm shoe lift under the non-paretic lower extremity during conventional physical therapy Control Group ($n = 6$): Range of motion exercises, strengthening, balance training, sit to stand and gait training on a treadmill and walking over obstacles	Weight-bearing symmetry: Digital Balance Scale Balance: BBS Gait Velocity: 10MWT At two weeks	Improvement in weight bearing symmetry in experimental group: 32.4 ± 0.06% pre, 37.9 ± 0.05% post and control group: 30.2 ± 0.04% before, 27.4 ± 0.06% after treatment with no statistical significance ($p = 0.44$); BBS in experimental group: 19.2 ± 3.1 pre, 41.2 ± 1.9 post treatment and control group: 13.2 ± 3.06 pre, 36.7 ± 2.4 post treatment with no statistical significance ($p = 0.46$); 10MWT in experimental group: 0.17 ± 0.02 m/s pre, 0.55 ± 0.2 m/s post treatment and control group: 0.17 ± 0.04 m/s pre, 0.28 ± 0.1 m/s post treatment with no statistical significance ($p = 0.51$)
Sungkarat et al.[12] 2011 RCT	n =35 acute stroke and chronic Three weeks for 60 minutes	The experimental group ($n = 17$): I-ShoWS with seven-degree lateral wedged insole under the non-paretic extremity and pressure sensor under paretic extremity during conventional physical therapy Control group ($n = 18$): Functional training, gait training, weight-bearing exercises and balance training	Weight-bearing symmetry: Digital Weighing Scale Balance: BBS and TUG Spatio-temporal gait parameters i.e., gait speed, step length asymmetry ratio and single support time asymmetry ratio: GAITRite At three weeks	Statistically significant changes in all outcomes i.e., weight-bearing symmetry, balance and gait were seen in the experimental group when compared to the control group. Gait speed ($p = 0.02$); step length asymmetry ratio and single support time symmetry ratio ($p = 0.03$); BBS ($p = 0.001$); TUG (0.04); Weight-bearing symmetry ($p = 0.004$)
Elsayed et al.[13] 2016 RCT	$n = 20$ chronic stroke Four weeks for 60 minutes	The experimental group ($n = 10$): 0.6 cm shoe lift under the non-paretic lower extremity during conventional physical therapy Control Group ($n = 10$) strengthening and stretching exercises, gait training on treadmill and stairs, balance training, and faradic stimulation for ankle dorsiflexors	Weight-bearing Symmetry: Digital Weighing Scales Balance: BBS Gait Velocity: 6MWT Step length using pen attached at the foot and walk on a sheet, an average of six-step lengths At the end of four weeks	A statistically significant change in BBS and gait velocity post-treatment in the experimental group when compared to the control group ($p = 0.05$, $p = 0.03$, respectively) No statistically significant change on weight-bearing symmetry and step length post-treatment in the experimental group when compared to the control group ($p = 0.3$, $p = 0.49$, respectively)

TABLE 2: (*continued*)

Author/type of study	Sample size/ study patients/ Intervention duration	Intervention	Outcome measures	Results
Krishna et al.[14] 2018 RCT	$n = 30$ Acute and chronic stroke Two weeks	Experimental Group ($n = 15$): Shoe insert of unknown height under the non-paretic lower extremity along with conventional physical therapy. Control Group ($n = 15$): Range of motion exercises, static and dynamic balance exercises, gait training on stairs, obstacles, and functional training like sit to stand exercises	Weight-bearing symmetry: Digital Weighing Scale Balance: BBS Gait velocity: 10MWT At post-treatment two weeks; Follow-up at 3 weeks, 6 weeks and 9 weeks	A statistically significant change in the experimental group on weight-bearing symmetry at 6 weeks and 9 weeks follow-up when compared to the control group ($p = 0.013$ and $p = 0.03$). No statistically significant change on BBS, gait velocity post-treatment and follow-ups in the experimental group when compared to the control group ($p > 0.05$)
Sheikh et al.[15] 2015 RCT	$n = 28$ chronic stroke Six weeks for 90 minutes	Experimental Group ($n = 14$): 0.6 cm shoe lift under the non-paretic lower extremity worn throughout the day and during conventional physical therapy Control group ($n = 14$) Strengthening and stretching exercises, functional training, gait training on a treadmill and walking over obstacles	Weight-bearing symmetry: Computerized force platforms Gait Velocity: 10MWT Spatio-temporal gait parameters i.e., SWSI, STSI and step length symmetry: video-based kinematic analysis At six weeks and three-month follow-up	A statistically significant change in weight-bearing symmetry at six weeks and three-month follow-up ($p = 0.008$, $p = 0.001$). No statistically significant difference was seen in gait velocity or spatiotemporal parameters. 10MWT: ($p = 0.95$) post treatment, ($p = 0.5$) at follow-up; STSI: ($p = 0.07$) post treatment, ($p = 0.13$) at follow-up; SWSI: ($p = 0.31$) post treatment, ($p = 0.09$) at follow-up; Step length symmetry: ($p = 0.13$) post treatment, ($p = 0.18$) at follow-up
Nam et al.[16] 2017 Three-arm RCT	$N = 45$ Acute and chronic stroke Four weeks for 30 minutes	Experimental Group (5CWST) ($n = 15$): 0.5 cm shoe lift under the non-paretic extremity during conventional physical therapy Experimental Group (10CWST) ($n = 15$): 1 cm shoe lift under the non-paretic extremity during conventional physical therapy Control Group ($n = 15$): Lower extremity strengthening on the ergometer and conventional physical therapy	Plantar pressure distribution (FF, MF and HF): force platform Gait parameters i.e., step length of the non-paretic side and walking velocity using RS scan system connected to the computer. At the end of four weeks	A statistically significant change in the 10CWST group when compared to both the 5CWST group and control group on plantar pressure in the HF post-treatment ($p < 0.05$). A statistically significant change in the 10CWST group on walking velocity and step length when compared to the control group post-treatment ($p < 0.05$)

TABLE 2: (*continued*)

Aruin et al.[17] 2018 RCT	$n = 10$ Chronic stroke Six weeks for 60 minutes	Experimental Group ($n = 5$): 0.4 cm textured shoe lift under the non-paretic lower extremity during conventional physical therapy Control Group ($n = 5$): Weight-bearing exercises pre-gait activities like stepping, sideways walking, single-leg stance, and gait training using assistive devices	Weight-bearing symmetry: Balance Master computerized force platforms Gait Velocity: TUG Spatiotemporal parameters of gait, i.e., STSI, SWSI and SSSI: GAITRite At six weeks and four-month follow-up	A statistically significant change in weight-bearing symmetry, STSI, SWSI and SSSI in experimental group post-treatment and at follow up when compared to control group ($p < 0.05$) A statistically significant change in gait velocity in the experimental group at four-month follow-up when compared to the control group ($p < 0.05$)
Kang et al.[18] 2015 Pre–Post Study	$n = 12$ chronic stroke Immediate effect	Patients were measured in a randomized order under the three conditions: no shoe lift, 0.5 cm shoe lift, and 1 cm shoe lift	Balance, i.e., A-L and M-L sway velocities: Good Balance System Assessment is done with and without insert on the same day	Statistically significant change: 1 cm shoe lift in both A-L and M-L sway velocities when compared to no shoe lift. ($p < 0.05$); 0.5 cm shoe lift in A-P sway velocity when compared to no shoe lift ($p < 0.05$)
Son[19] 2017 RCT	$n = 36$ Acute and chronic stroke Four weeks for 30 minutes	Experimental Group (5CWST) ($n = 12$): 0.5 cm shoe lift under the non-paretic lower extremity during conventional physical therapy Experimental Group (10CWST) ($n = 12$): 1 cm shoe lift under the non-paretic lower extremity during conventional physical therapy Control Group ($n = 12$): Lower extremity strengthening on the ergometer and conventional physical therapy	Static Balance with A-P and M-L sway velocities: Good Balance System Dynamic Balance with A-P and M-L distances: Good Balance System At end of four weeks	A statistically significant change with 10CWST group on A-P sway velocity, M-L sway velocity and M-L distance when compared to control group at four weeks ($p < 0.05$) A statistically significant change with 10CWST group on A-P sway velocity when compared to 5CWST group at four weeks ($p < 0.05$)
Liao et al.[20] 2018 Three-arm RCT	$n = 56$ Chronic stroke Six weeks for 20 minutes	Experimental Group (LW) ($n = 19$): Five-degree lateral wedge shoe insole under the non-paretic lower extremity during standing and walking activities Experimental Group (BT) ($n = 18$): weight shift training on the Biodex Balance System with conventional rehabilitation Control Group ($n = 19$): Conventional physical therapy	Balance: balance CAT Gait Velocity: TUG At six weeks; follow-up at 10 weeks and 18 weeks	A statistically significant change in balance CAT and gait velocity post-treatment and follow-up at 10 weeks and 18 weeks in the LW group when compared to the control group ($p < 0.05$)

TABLE 2: (*continued*)

Author/type of study	Sample size/ study patients/ Intervention duration	Intervention	Outcome measures	Results
Fortes et al.[25] 2020 Pre–Post study	$n = 42$ Chronic stroke Immediate Effect	Shoe lift of 1.5 cm under the non-paretic lower extremity compared to no shoe lift	Gait Velocity: 10MWT Functional Mobility: TUG	A statistically significant change on 10MWT and TUG with shoe lift when compared to no shoe lift ($p < 0.05$)
Ma et al.[26] 2018 Pre–Post study	$n = 17$ Chronic stroke Immediate effect	0.4 cm textured shoe lift under the non-paretic lower extremity and compared with no shoe lift	Gait parameters, i.e., gait velocity, cadence, step width, step length, STSI, SSSI and COP: GAITRite	A statistically significant change in STSI, SSSI and COP with use of shoe lift when compared to no shoe lift ($p < 0.01$)

*A-P, anteroposterior; BBS, Berg balance scale; CAT, computerized adaptive test; CBWS, compelled body weight shift; COP, centre of pressure; CWST, constrained weight shift training; CPT, conventional physical therapy; FUT, forced use therapy; FWV, fastest walking velocity; I-ShoWS, insole shoe wedge and sensors; M-L, mediolateral; PWV, preferred walking velocity; RCT, randomized control/clinical trials; SSI, spatial symmetry index; SSSI, single stance symmetry index; STSI, stance symmetry index; SWSI, swing symmetry index; TSI, temporal symmetry index; TUG, timed up and go; 10MWT, 10 meter walk test group when compared to the control. Shoe lifts of height 0.6 cm were used in four studies,[1,6,13,15] which showed improvements in weight-bearing symmetry post-treatment, along with carry-over effects at three-month follow-up.[1,15] Yet another study evaluated the application of both 0.5 cm and 1 cm shoe lift and compared it with no shoe lift under the paretic lower extremity. There was a statistically significant change in the weight-bearing symmetry with improved plantar pressure at the hindfoot in the group that received a 1-cm shoe lift. In contrast, the group that received a 0.5-cm shoe lift failed to show any significant change.[16] A 0.4-cm shoe lift under the paretic lower extremity showed significant improvement in weight-bearing symmetry post-treatment and at follow-up compared to no shoe lift ($p < 0.05$, effect size = 0.53).[17]

3. On the Duration of CBWS

In two studies, there was a significant improvement in patients in the experimental group within six weeks of CBWS.[15,17] In contrast, there was no significant improvement in weight-bearing symmetry[1] when compared to the control group. Studies that used CBWS therapy for two weeks[6,14] and four weeks[13,16] reported no significant change in the weight-bearing symmetry in the experimental group compared to the control group (effect size > 0.8). A three-week intervention period of CBWS showed significant improvement in weight-bearing symmetry in the experimental group (effect size of 0.75) compared to the control group.[12]

B. Effects of CBWS on Balance

In total, eight studies analyzed the effect of CBWS on balance; of which 5 studies used BBS,[1,6,12–14] 2 studies used Balance Master System[18,19] and one used Balance Computerized Adaptive Test (CAT).[20]

1. On Post-Stroke Duration

The effects of CBWS on balance, when assessed in acute stroke patients, revealed a clinically significant change in BBS scores among the experimental group when compared to the control with a mean change higher than the MCID for acute stroke (MCID > 6) on BBS[21] (effect size > 0.8).[6]

Four studies evaluated the effect of CBWS on balance in chronic stroke patients. Two studies showed clinically significant change (MCID > 2.67 for chronic stroke)[22] in the balance performance in the experimental group compared to the control post-treatment[1,13] with carry-over effects at three-month follow-up[1] ($p < 0.05$, effect size > 0.8). One study that used the Balance Master System reported a statistically significant change in A-P and M-L sway velocities when CBWS was delivered with shoe lift under paretic extremity compared to no shoe lift ($p < 0.05$, effect size = 1.3).[18] With a shoe wedge placed under the paretic lower extremity to deliver CBWS, a statistically significant improvement was noticed in balance score (effect size = 0.96) with retention of training on subsequent follow-up at 10 weeks (effect size = 1.28) and 18 weeks (effect size = 1.10).[20]

Three studies included patients with both acute and chronic stroke, where one study that used a wedge insole under the non-paretic lower extremity showed both clinically and statistically significant change on BBS post-treatment in the experimental group (effect size = 0.66).[12] In contrast, another study revealed neither clinical nor statistically significant balance improvement post-treatment (effect size = 0.02) but showed clinically significant change at nine weeks follow-up ($p = 0.01$, effect size = 0.97).[14] The effect of shoe lift under paretic lower extremity on balance reported a significant improvement in the A-P and M-L sway velocities during static balance assessment and had an increased reach distance mediolaterally on dynamic balance evaluation compared to no shoe lift (effect size > 0.8).[19]

2. Type of Shoe Inserts: Lifts and Wedges

Three studies[1,6,13] used shoe lifts of 0.6 cm under the non-paretic lower extremity and evaluated their effects on balance. Two studies showed clinically significant balance improvement in the experimental group compared to the control group post-treatment ($p < 0.05$, effect size > 0.8).[6,13] Similarly, a clinically significant change was reported in chronic stroke patients post-treatment and at three-month follow-up on BBS in the experimental group compared to the control group.[1] One study that used a shoe lift of unknown height under the non-paretic lower extremity reported neither statistical nor clinically significant change post-treatment (effect size = 0.27, MCID < 6) but showed clinically significant change at nine-week follow-up (effect size = 0.02).[14] Shoe lift of 1 cm under the non-paretic lower extremity had a superior effect on the A-P and M-L sway velocities as reported by two studies[18,19] when compared to a 0.5-cm shoe lift and no shoe lift (effect size > 0.8).

A five-degree lateral wedge insole under the non-paretic lower extremity showed statistically significant change on balance CAT post-treatment and at 10 and 18 weeks follow-up in the experimental group compared to the control group.[20] Similarly, CBWS using a seven-degree lateral wedge insole under the non-paretic lower extremity of chronic stroke patients reported both clinical and statistically significant change (MCID > 2.67,[22] effect size = 0.78) compared to no insole.[12]

3. On the Duration of CBWS

When acute stroke patients received CBWS for 2 weeks, a clinically significant change was noted in balance among the experimental group compared to control in one of the studies with effect size > 0.8[6]; and another study which compared the effects only after nine weeks follow up revealed the same (effect size = 0.02).[14] With CBWS intervention for six weeks, two studies reported improvement in balance performance among the experimental group with carry-over effects during follow-up and was clinically significant (effect size > 0.8).[1,20] CBWS given for three weeks[12] and four weeks[13,19] both showed clinical and statistically significant improvement on BBS scores (effect size > 0.8),[12,13] and statistically significant improvement in both A-P and M-L sway velocities with shoe lift when compared to no shoe lifts (effect size > 0.8).[19] One study reported the immediate effect of shoe lift under the paretic lower extremity, which was statistically significant in A-P and M-L sway velocities compared to no shoe lift ($p < 0.05$, effect size > 0.8).[18]

C. Effects of CBWS on Gait

1. On Post-Stroke Duration

When evaluated with a shoe lift under the non-paretic lower extremity, gait velocity in patients with acute stroke reported a clinically significant change on 10MWT in the experimental group with the mean change score more than the MCID (0.16 m)[23,24] when compared to the control group (effect size = 1.8).[6]

Six studies[1,13,15,17,20,25] on chronic stroke patients evaluated effect of CBWS on gait velocity. Three studies failed to report both clinical and statistically significant change on 10MWT post-treatment[1,15,25] and at follow-up[1,15] (effect size < 0.5), however, one study showed a statistically significant change on 6MWT among the experimental group compared to the control (effect size = 1.78).[13] Two studies[17,20] reported clinically and statistically significant improvements on TUG post-treatment and at follow-up in the experimental group compared to the control group (effect size > 0.8). Three studies[15,17,26] evaluated the effect of CBWS on spatiotemporal parameters of chronic stroke patients using GAITRite and revealed significant changes in SSSI, SWSI, and STSI parameters post-treatment (effect size > 0.8)[26] and at follow-up[17] (effect size > 0.8); however, no statistically significant change was demonstrated post-treatment and three-month follow-up in the experimental group when compared to control group (effect size > 0.8).[15]

Studies that included both acute and chronic stroke patients showed clinically significant improvement in the experimental group on TUG (effect size = 0.46)[12] and 10MWT (effect size = 0.42)[14] with carry-over effects at follow-up[14] when compared to the control group. Significant improvements in step length were observed in the group with shoe lifts under the non-paretic extremity compared to no shoe lift (effect size = 0.06).[16]

2. On Type of Shoe Inserts: Lifts and Wedges

Shoe lifts of 0.6-cm height under the non-paretic lower extremity were used for CBWS in four studies[1,6,13,15] and three studies reported clinically significant improvements in gait velocity on 10MWT[1,6,15] in the experimental group compared to the control (effect size < 0.7). Two studies evaluated the spatiotemporal parameters where one study[13] reported statistically significant improvements in step length; however, the other study[15] reported no significant improvement on SWSI, STSI, and SSSI parameters in the experimental group when compared to the control group ($p > 0.05$, effect size > 0.8).

Two studies that used a shoe lift of 0.4 cm under the non-paretic lower extremity showed significant improvement[26] on SWSI and STSI parameters along with carry-over effects observed at follow-up[17] (effect size > 0.8) when compared to no shoe lift. Patients who received CBS with a shoe lift of 1 cm under the non-paretic lower extremity revealed better step length of the paretic lower extremity when compared to no shoe lift (effect size = 0.53).[16] Gait velocity was evaluated in a study[14] with shoe lift of unknown height using 10MWT reported clinically significant improvement post-treatment and at follow-up. Similarly, CBWS with a shoe lift of 1.5 cm under the non-paretic lower extremity reported clinically significant immediate effects on 10MWT compared to no shoe lift (effect size = 0.06).[25]

A five-degree lateral shoe wedge was used to provide CBWS therapy in two studies[5,20] and its effect on gait velocity, and spatiotemporal gait parameters were reported; the experimental group showed a statistically significant change in walking speed and symmetry index compared to the control group ($p < 0.05$, effect size > 0.8). Similarly, when a seven-degree lateral wedge insole was used, the experimental group improved with respect to step length symmetry, SSSI, SWSI, and gait velocity on TUG more than 2.9 seconds (MCID),[24] compared to the control group.[12]

3. On the Duration of CBWS

An immediate effect of CBWS on gait velocity using 10MWT[25] and SWSI, STSI, SSSI, and COP on GAITRite[26] was assessed in two studies; both reported clinically significant changes with the group that received shoe lift when compared to no shoe lift (effect size > 0.8). When CBWS was given for four weeks, a significant change in the step length was seen in two studies; both studies showed significant improvements in the experimental group compared to the control group.[13,16] Three studies[5,6,14] with two-week intervention reported significant changes in gait velocity on 10MWT[6,14] and TUG[5] in the experimental group with shoe insoles under the non-paretic lower extremity post-treatment and at follow-up[14] (effect size < 0.7). Patients who underwent CBWS for three weeks showed a clinically significant improvement in gait velocity on TUG, with the mean difference being more than the MCID of 2.9 seconds reported in stroke patients (effect size = 0.46) and spatiotemporal parameters, i.e., step length and stance time symmetry on GAITRite with a shoe insole under the non-paretic lower extremity (effect size > 0.8).[12]

IV. DISCUSSION

Disturbance in balance and gait after stroke are major problems that increase the level of dependency for activities of daily living, further increasing the risk of falls. Many physical rehabilitation approaches have been used to improve weight symmetry, balance, and gait patterns. CBWS therapy uses a shoe lift on the non-paretic side during conventional physical therapy to improve symmetry of stance and weight-bearing of the paretic lower extremity. Hence, the purpose of this review was to consolidate all the evidence about the effect of CBWS on weight-bearing symmetry, balance, and gait in patients with stroke.[1,15,17]

A. Characteristics of CBWS

A possibility of causing artificial leg-length inequalities with the use of a shoe lift of 2.5-cm height is considered to be cosmetic rather than an etiological factor for stress fractures in lower extremities. Therefore, the use of shoe height of 1 cm and below have avoided the possibility of causing leg-length inequalities.[27] Studies showed that a 1 cm shoe lift was more beneficial in improving both balance and gait when compared to a 5-mm shoe lift and no shoe lift.[16,18] One study also made use of I-ShoWS, a somatosensory and audio feedback device that consisted of a seven-degree lateral wedge insole under the non-paretic extremity and pressure sensors embedded under the paretic extremity insole during gait training proved to be beneficial in terms of improving gait parameters such as swing and stance symmetry along with gait velocity on TUG with the mean difference being more than the MCID in stroke patients.[12] It was observed that during the entire gait cycle, 7.2° subtalar eversion occurs in 44% of healthy individuals.[28] Previous studies showed the application of lateral wedge insoles up to seven-degree would cause subtalar eversion within normal ranges, thus having no negative effect on the gait of a healthy individual.[2] On the other hand, shoe lifts used for CBWS training showed weight-bearing symmetry along with balance and gait, having a clinically significant change that was more than the MCID values for balance on BBS and gait velocity on TUG.[1,6,16,18,25] However, a previous study that compared both uses of wedges and lifts as CBWS concluded lateral wedge insoles had a better effect gait symmetry ratios when compared to lifts.[2] According to the studies included in the review, studies that included acute stroke patients[6,5,16,19] observed a clinically significant change in balance and gait parameters like stance symmetry, swing symmetry, and gait velocity with a score more than MCID on BBS and TUG when compared to the chronic stroke patients.

B. CBWS and Weight-Bearing Symmetry

Weight-bearing asymmetry is considered to be a variable that influences balance and gait in stroke patients.[19] A shoe insert under the non-paretic lower extremity would compel the individual to shift more weight on the paretic extremity. This followed a prior study on healthy individuals, which showed that a textured insole placed under one lower extremity was associated with an increased asymmetrical position of the pelvis leading to forced weight bearing onto the other extremity.[29] Application of a shoe insert under the non-paretic lower extremity showed improvements in the paretic lower extremity weight-bearing. This finding was also concurred by a study[14] where authors stated that a shoe insole would help maintain symmetry in weight-bearing, thus avoiding the development of learned disuse of the involved extremity. An observation on the cortical representation of the stroke patients with left-side hemiparesis showed improvement by 8.7% in weight-bearing symmetry and gait while ones with right-side improved only by 0.89% suggesting CBWS be tailored to patients with a right-sided stroke rather than left-sided stroke as they required more time to improve the asymmetry onweight-bearing.[6] This observation is in line with prior studies, which showed patients with left cortical infarction put > 50% of their weight on their non-paretic lower extremity, while those with right cortical infarction put < 50% of their weight on their non-paretic side. Furthermore, patients with right cortical infarction had the reduced ability to consciously shift weight onto their non-paretic extremity, compared with those with left cortical infarction. It further adds to the importance of the right cortical area in controlling stability in quiet stance and consciously shifting weight from one side to the other.[30]As both CBWS and control groups were administered with similar physical rehabilitation protocols, improvements in weight-bearing symmetry were seen in both groups, but a clinically significant change in the CBWS group could be attributed to the application of the shoe insert.[1,15] On the contrary, worsening of weight-bearing symmetry in the control group was attributed to the learned disuse of the paretic lower extremity and not because of impaired ability to bear weight, making the stance more asymmetrical.[6] Hence, when a patient presents with weight-bearing asymmetry the therapist should always consider using CBWS while delivering conventional stroke rehabilitation. It will enhance weight-bearing symmetry and prevent worsening of functional outcomes of the patient. One study in this review attributed the gain in muscle strength after CBWS as a contributing factor for improved symmetry in weight-bearing,[12] as increased weight bearing on the paretic extremity facilitates load-receptor feedback to the central nervous system and that leads to an increase in the muscle strength.[19] This observation was supported by a study[13] where a paretic lower extremity muscle activation improved with 0.5- and 1-cm insert under the non-paretic lower extremity.

C. CBWS and Balance

Balance improved in line with weight-bearing symmetry at the end of the intervention showing statistical and clinically significant change[1,6] while there was a marginal drop at the three-month follow up in the CBWS group reported by Aruin et al.[1] One possible reason could be the inclusion of chronic stroke patients and prior studies which included chronic stroke patients, failed to exhibit an evident change in motor recovery due to development of learned helplessness combined with an inability to perform ADLs.[31,32] On the contrary, a study showed retention of training effect at the end of nine-week follow-up, which could be due to the inclusion of patients with both acute and chronic stroke. Balance is measured based on A-P and M-L sway velocities. Improved weight-bearing symmetry would not necessarily imply a clinically significant improvement in balance measures. This statement follows Sungkarat et al.,[12] who illustrated a statistically significant increase in the post-intervention score on BBS that was not clinically important. A reduction in the sway velocities in the CBWS group was due to the shoe insert placement under the non-paretic lower extremity, forcing the center of gravity to shift from the non-paretic side to the midline.[14] Furthermore, increased weight bearing on the paretic extremity facilitated load-receptor feedback to the central nervous system, thus improving static and dynamic balance in patients with stroke.[19] According to the studies included in the review, it has been seen that studies that included acute stroke patients[6,12] observed a clinically significant change in balance scores on BBS along with A-P and M-L sway[18,19] velocities when compared to the studies with chronic stroke patients.[1,13,17,20]

D. CBWS and Gait

An earlier study concluded that the use of modified constrained induced movement therapy (CIMT) promoted better weight-bearing symmetry in comparison to CBWS therapy. CIMT ideally helps reduce the learned disuse of the paretic extremity and hence maximizes neuroplasticity.[3] Moreover, previous studies have also mentioned the inability to implement CIMT alongside gait rehabilitation for patients with hemiparesis by restraining the non-paretic extremity making ambulation unattainable.[1] Instead, CBWS, with the help of a shoe insert, can be used as an add-on during gait rehabilitation, providing augmented feedback that will help rectify gait abnormalities. During gait, weight transfer onto the non-paretic limb is essential for the forward displacement of the paretic limb[33]; the forward stepping can be further enhanced by placing the paretic foot on a high step.[11] According to previous studies increased weight-bearing on the non-paretic limb in quiet standing increased the contribution of the non-paretic extremity to balance control, reducing the weight-bearing capacity of the paretic limb. These changes further led to increased asymmetry in both spatial and temporal gaitparameters.[34] CBWS during gait rehabilitation demonstrated improvements in the gait velocity meant that stroke patients required a reduced amount of time to complete a particular distance. In this study, authors stated improvement in gait velocity parallel to the improvement in weight-bearing symmetry due to administration of a 0.6-cm shoe insert under the non-paretic lower extremity.[13] On the contrary, in another study no change in the gait velocity was observed with the application of shoe insert under the non-paretic lower extremity.[26] A prior study proved a textured insole placed under one extremity demonstrated improved gait velocity.[29] Prior studies showed that hemiparetic patients use the AFO on the paretic extremity for more ankle and knee stability during standing and walking. With CBWS, using the shoe wedge together with the AFO in gait retraining during the first 6 months post-stroke is shown to be beneficial for maximum recovery.[2] Clinically significant results based on MCID scores[23,24] were reported in patients who were allowed the use of assistive devices or AFOs during TUG or 10MWT where 18 patients made use of a walking aid and 25 patients used an AFO, thus implying CBWS administered with an assistive device enhances its impact on the gait parameters in stroke patients.[25] Similarly, an improvement in gait velocity was observed with the application of I-SHoWS that emphasized loading of the paretic extremity during standing and gait training.[12] Although studies[1,5,6,12–17,25,26] that evaluated spatial and temporal parameters of gait on chronic stroke patients found improvements in gait velocity and overall temporal symmetry; increased cadence or gait velocity does not necessarily indicate an improvement in the spatial parameters of gait. This statement is in line with a study[15] where overall temporal symmetry and gait velocity showed improvements from baseline, but the stance symmetry did not show any change in both experimental and control groups. The reduced weight bearing on the paretic extremity during standing would lead to a decreased capacity to translate even during walking, reducing stance time symmetry duringgait.[34] It has been shown that biofeedback training can have a prolonged positive effect on stance symmetry.[35–37] This relationship between weight-bearing asymmetry in quiet stance and stance time symmetry in gait implies combining CBWS with other therapy, which focuses on improving stance time symmetry during gait rehabilitation.

V. LIMITATIONS

Although this review is homogeneous based on the study design considered, generalization on the post-stroke duration and the number of treatment sessions required could not be made.

VI. CLINICAL IMPLICATIONS

This review targets the effects of using CBWS on weight-bearing symmetry, balance, and gait, which is one of the most important components of stroke rehabilitation. CBWS is a cost-effective and feasible technique for achieving symmetry in weight-bearing among stroke patients and can be easily practiced in the clinical setup. The shoe insert can be used for augmenting feedback during rehabilitation by embedding auditory or pressure sensors. It is a training protocol aimed at increasing symmetrical weight distribution during standing and walking that may consequently result in gait and balance improvement. It can be strongly recommended as an add-on to conventional physiotherapy treatment.

VII. CONCLUSION

CBWS using shoe lifts and wedges of different heights under the non-paretic lower extremity during conventional stroke rehabilitation effectively improved weight-bearing symmetry. Shoe lifts were effective in improving balance and weight-bearing symmetry, whereas the use of shoe wedges led to improvements in spatiotemporal gait parameters because of the additional subtalar eversion provided in the wedge. Lateral shoe wedges angled up to seven degrees along with gait rehabilitation has shown to be of utmost benefit concerning improvements in gait parameters such as gait velocity, step length symmetry, and single support stance time on the paretic lower extremity. Furthermore, the use of shoe lifts with a height above 1 cm along with biofeedback postural training has shown to be effective in training both static and dynamic balance in patients with stroke. Most studies included in the review applied CBWS during the therapy sessions, which lasted for 60 to 90 minutes per day for a period of 3 to 6 weeks and showed improvements in weight-bearing symmetry, balance, and gait in stroke patients. Further studies should be conducted to establish a standard protocol for the use of CBWS based on the duration of the use of the shoe lift and the number of treatment sessions. Also, studies could evaluate the effects of wearing the shoe insert throughout the day for a shorter time frame to ensure adherence and early improvement in weight-bearing symmetry, balance, and gait.

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